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Bio Intelligence Service - Scaling sustainable development:
Industrial ecology · Nutritional health

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Executive summary

Context

Climate change is one of the biggest environmental challenges of the 21st Century and has been the subject of increasing political attention worldwide. Various scientific sources link the climate change directly to the increasing Green House Gases (GHG) emissions, and more specifically CO₂ emissions. Rising CO₂ emissions are pushing up earth's carbon stock and increasing global temperatures.

Three targets were presented by the European Commission (EC) on January 23rd 2008, in the **integrated proposal for climate action**. The three EU policy targets are:

- A reduction of at least 20 % in GHG emissions by 2020¹
- A 20 % share of renewable energies in EU energy consumption by 2020.
- A 20 % reduction of the EU's total primary energy consumption by 2020 through increased energy efficiency

Achieving 20 % savings of energy consumption by 2020 through energy efficiency is underlined as one of the key ways in which CO₂ emission savings can be realised². Earlier, the Green Paper for Energy Efficiency (March 2006) had also identified energy efficiency as the most effective, most cost-effective and rapid manner for reducing greenhouse gas emissions. Finally, in the recent Communication³ "Addressing the challenge of energy efficiency through Information and Communication Technologies" (May 2008) the EC identified that Information and Communication Technologies (ICT) have an important role to play in reducing the energy intensity⁴ and increasing the energy efficiency of the EU economy.

In this context, this study examines the impacts of Information and Communication Technologies (ICT) on the energy efficiency in Europe with a 2005-2020 outlook. This work deals with the interrelated issues of energy efficiency, renewables and energy production, and GHG emissions. This study analyses not only the environmental footprint of the ICT sector itself, but also the effects of using ICT applications in support of higher energy efficiency and energy savings in other areas (building,

¹ Rising to 30% if there is an international agreement committing other developed countries to "comparable emission reductions and economically more advanced developing countries to contributing adequately according to their responsibilities and respective capabilities".

² 20 20 by 2020 - Europe's climate change opportunity, COM(2008) 30 final - 23 January 2008

³ Addressing the challenge of energy efficiency through Information and Communication Technologies COM(2008) 241 final – 13 May 2008

⁴ The energy intensity is defined as : *The amount of energy required to produce a unit of Gross Domestic Product (GDP) (in COM(2008) 241 final)*

industry, and energy) (Task 2). Further, the study also explores the use of ICT applications in support of dematerialisation practices (Task 3).

In order to analyse and estimate the potential that ICT-based applications can provide, various scenarios were developed for each of the areas investigated:

- *Baseline scenarios* (reference scenarios) mainly based on data from the literature, these scenarios do not take into account the increase in the use of ICT-based applications. These scenarios are the reference against which the alternative scenarios are evaluated.
- *Business-as-Usual scenarios* (BAU) which assume continuity is maintained considering the current situation and trends (market, technology, policy, etc.).
- *Eco-scenarios* which assume that there is a push (market based or technology based) for ICT-based energy efficient solutions (assuming higher improvement potential and/or higher uptake of energy efficient ICT-based technologies).

In cases, where robust quantified data could not be obtained, “low”, “medium” and “high” assumptions were used in order to provide a reasonable range of data and order of magnitude.

A bottom-up approach was used to develop these scenarios. To begin with, case studies were identified which could provide quantified data regarding the improvement potential enabled by ICT applications in different sectors. Then extrapolation of the data from these case studies was made to the EU-27 level and at a horizon of 2020, taking into consideration market trends, technology trends, current and future policy frameworks and business initiatives e.g. Eco-design Directive, Directive on energy efficiency and energy services, Directive on the Energy Performance of Buildings, and voluntary initiatives such as Energy Star, EU Codes of Conduct, Climate savers computing initiative, and Greengrid.

The scenarios development, the implied necessary assumptions and restrictions of the scope (i.e. not all aspects could be covered in the study) and the methodology lead to some limitation mainly because of the unavailability of reliable data on status and trends for all ICT-based energy efficiency enabling technologies. However, the results of this study still provide a good order of magnitude.

Task 1: The ICT sector (2005-2020)

This task analysed the impacts of the ICT sector itself. It assessed the total electricity consumption of ICT equipment during the use phase (both in terms of ICT end-user devices and Infrastructure). End of life phase and production phase were also investigated.

The analyses shows that total electricity consumption related to ICT end-user-equipment and ICT infrastructure amounts to **214.5 TWh** for the reference year 2005

(i.e. **8 % share of total EU-25 electricity use**). This is equivalent to 98.3 Mt CO₂ equivalent⁵ (i.e. **1.9 % of the total CO₂ emissions** of the EU-25 in 2005⁶).

The projections of BAU scenario shows that in 2020, the ICT sector could consume 409.7 TWh (187 Mt CO₂ equivalent⁶) which represents 10.5 % of the total EU-25 electricity consumption (i.e. 4.2 % of EU-25 CO₂ emissions) in contrast to an electricity consumption of **288.2 TWh in the Eco-scenario** (i.e. 132.1 Mt CO₂ equivalent⁶) **which represents 7.4% of the total EU-25 electricity consumption** (i.e. about 3 % of the EU-25 CO₂ emissions).

This shows that the increase in the stock of ICT appliances and network infrastructure combined with an extending power-on periods will lead to a **significant increase in the carbon footprint of the ICT sector**, despite the development of **energy efficient technologies** and the **miniaturisation of ICT devices which is encouraged by market forces**.

In parallel, the **demand on servers and data storage capacity is estimated to drastically increase** due to the extensive utilisation of ICT end-user devices. The study also provides estimate for EU-27 (see Table 1 , Figure 1, and Figure 2).

Table 1: EU wide estimates of the ICT sector electricity consumption

	2005	2020 BAU	2020 ECO
Total ICT sector electricity use in EU 25 (TWh/a)	214.5	409.7	288.2
ICT sector without consumer electronics in EU-25 (TWh/a)	118.6	245.1	185.2
Total ICT sector electricity use in EU-27 (TWh/a)	216.0	433.1	304.7
ICT sector without consumer electronics in EU-27 (TWh/a)	119.4	259.1	195.8
Share of the ICT sector electricity use over total EU-27 electricity use (%)	7.8%	10.9%	7.7%
Share of the ICT sector electricity use (without consumer electronics) over total EU-27 electricity use (%)	4.3%	6.5%	4.9%

⁵ For converting the electricity into CO₂ eq. we used the carbon emission factor used by the EuP EcoReport tool which the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh). This factor was assumed to remain constant throughout the 2005-2020 period.

⁶ EU 25 CO₂ in 2005 = 4923.3 MtCO₂ (source : European Environmental Agency, Annual European Community greenhouse gas inventory 1990 - 2006 and inventory report 2008)

Figure 1: BAU-scenario until 2020 – ICT sector total electricity use (use-phase) (EU-25)

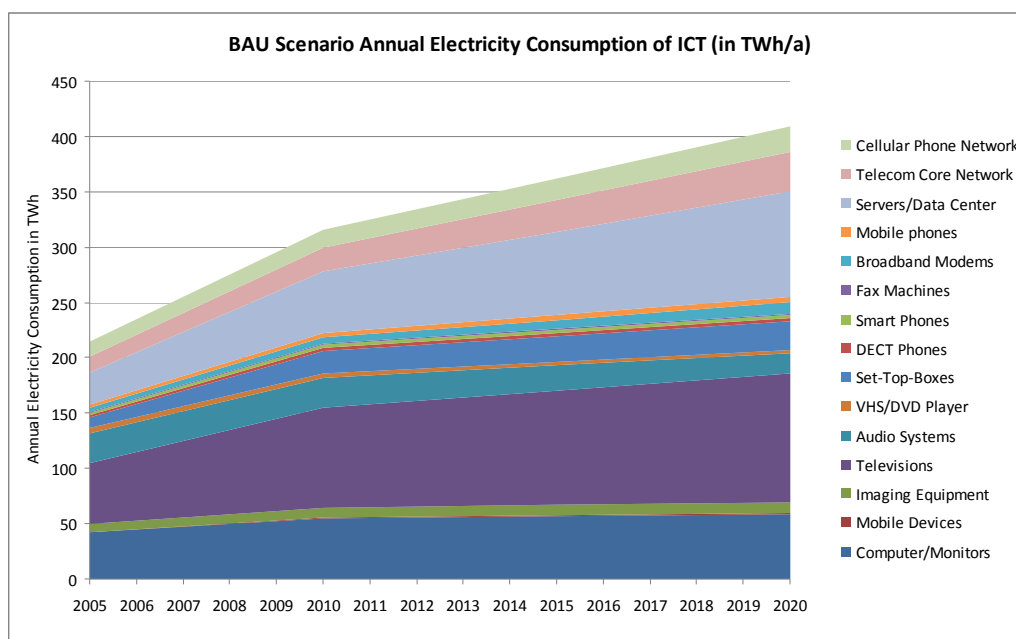
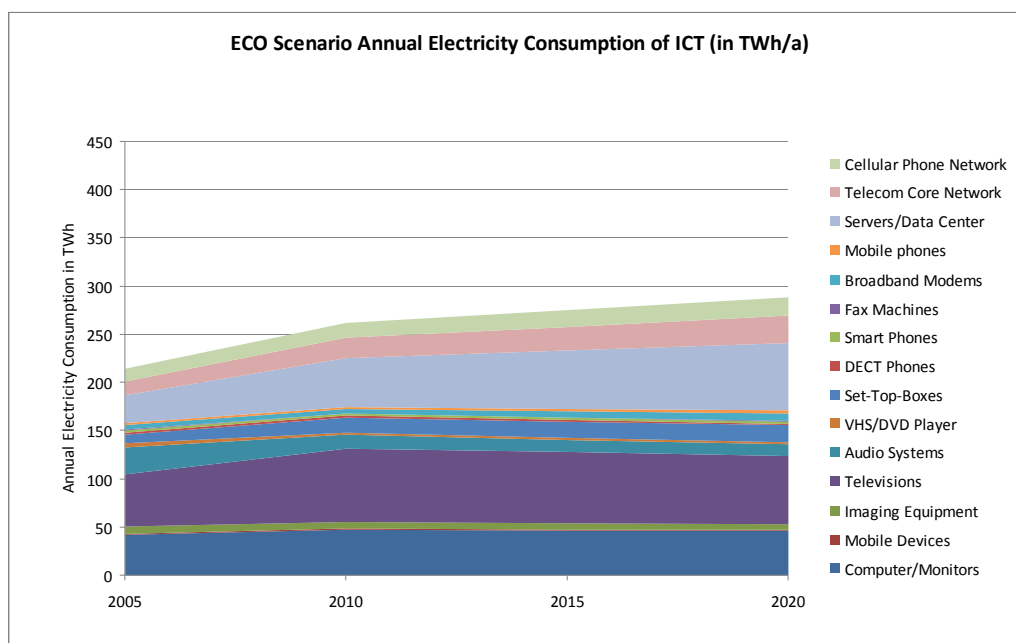


Figure 2: Eco-scenario until 2020 – ICT sector total electricity use (use-phase) (EU-25)



General recommendations in order to reach the targets set by the Eco-scenario include:

- Information to consumers to promote value efficiency and life cycle cost over purchase costs
- Adoption of a European Green Public Procurement scheme
- Extension of the European Energy Star labelling program or of the Energy label to other ICT devices (with priority on the products with significant energy consumption)

- Develop financial incentives to foster green products
- Ensure that innovation in R&D is rewarded through appropriate means (e.g. tax credit)
- Encourage further research activities towards more energy efficient ICT components and systems

The total electricity consumption of the ICT sector should however be put into perspective with the potential energy savings enabled by the use of ICT technologies in other sectors such as the buildings sector, the energy sector, the industry and in the service sector, which is the focus of Task 2.

Task 2: Quantification of Energy Efficiency in other sectors enabled by ICT Applications – 2020 Outlook

Task 2 analysed the impacts of ICT-based applications in:

- Buildings
 - Heating Ventilation Air Conditioning (HVAC) systems: HVAC systems were analysed considering the potential efficiency gains enabled by ICT control and monitoring capabilities (e.g. temperature monitoring and heating control, switchable vacuum insulated panels, switchable mirror film on windows, integrated cooling of ICT equipment, integrated control of clean room conditions).
 - Lighting systems: increased energy efficiency of lighting systems through ICT-based lighting technologies (e.g. LED lighting) and control systems were also explored (e.g. occupancy and daylight sensors).
- Industrial equipment and automation
 - Electrical drivers (motors, pumps and fans): increased energy efficiency based on ICT technology in motors was the main point of focus.
- Energy grid
 - The development of a supply and demand management system supported by ICT technologies and of the potential savings it could bring was analysed.

The analysis shows that in the Eco-scenario:

- Energy consumption of residential buildings could be reduced by almost 35 % which represents a saving of 1766.6 TWh/a (151.9 Mtoe). In the service sector, the energy consumption of buildings could be reduced by 17.2 % which represents 348.TWh (30 Mtoe). The important savings in the buildings sector need to be considered in perspective with the overall significance of the building's sector in Europe which represents over half of the electricity consumption in Europe (EU 27).
- The industrial sector could reduce its energy use for electrical drivers (motors) by almost 10% leading to a saving of 134.9 TWh/a (11.6 Mtoe)

- The energy sector (Energy Grid) could reduce its primary energy consumption by 37.2 Mtoe. This primary energy could produce (in theory) 148 TWh of electricity⁷ which is equivalent to 12.8 Mtoe⁸.

This means a total saving of 2 398 TWh (equivalent to 60 % of EU-27 total projected electricity use for the year 2020) compared to a total of 521 TWh savings (equivalent to 13 % of EU-27 total projected electricity use for the year 2020) in a BAU scenario.

Main recommendations suggested for achieving the Eco-scenario include: further support of multidisciplinary R&D and Innovation demonstrating the potential of ICT-based solutions, improvement and monitoring of statistical data, regulatory watch (initiating and monitoring self-regulation), information and guidelines, public and private partnership developments.

Task 3: Quantification of Energy Efficiency through dematerialisation by the use of ICT applications – 2020 Outlook

This task showed that the implementation of ICT applications in favour of dematerialisation in various areas could potentially provide energy savings through increased energy efficiency and reduction in the consumption of other resources (e.g. paper, CD material).

Main areas which were investigated include e-government (focus on e-health and e-taxation), Audio/video conferencing, e-work, Dematerialisation of materials and services (including e-ticketing, mobile ticketing, e-banking, e-invoicing, digital music, e-books, and virtual answering machines), e-commerce, RFID applications (Radio-Frequency IDentification), CAD (Computer Aided Design), and virtual reality applications. In order to provide robust analyses, the scenarios were limited to the following dematerialisation practices for which reliable data on status and trends could be obtained:

- e-government (focus on e-health and e-taxation)
- Audio/video conferencing
- e-work
- Dematerialisation of materials and services (e-ticketing, mobile ticketing, and digital music)

The analysis of Task 3 shows that in the Eco-scenario, the dematerialisation practices (mainly teleworking and videoconferencing) could provide energy savings equivalent to 0.8 % of EU-27 total electricity consumption (projected data for the year 2020) which is equivalent to 0.6 % savings in the EU-27 total CO₂ emissions.

⁷ Calculations based on the EuP EcoReport factor: 1 MWh electricity = 10500 MJ= 0.251 toe primary energy

⁸ 1 toe = 11.63 MWh

These relatively “low” savings provided by the “dematerialisation” in this report need to be interpreted with care. This limited calculation does not reflect the potential of dematerialisation in Europe if all other dematerialisation practices (listed above) were included in the analysis. This, however, was not feasible mainly because of the unavailability of reliable data on status and trends of other dematerialisation practices.

In the case of dematerialisation through RFID and CAD/virtual reality, the lack of available data and the variety of existing applications prevented any extrapolation or quantification at EU level. However, some case studies indicate that opportunities for saving time, energy and resources could be created by ICT applications in this domain.

Main actions to achieve energy efficiency through ICT application in dematerialisation include: improvement and monitoring of statistical data, financial incentives to promote the uptake of selected dematerialisation practices, support of public/private partnerships (e.g. in transport), information and guidelines, technology development (e.g. improvement of internet transaction security), and harmonisation in various areas such as eco-assessment methodology, eco-assessment data, data compatibility, and also of existing and upcoming environmental legislation.

ICT for Energy Efficiency?

The study shows that the overall net energy savings⁹ enabled by ICT-based technologies are positive both in the BAU and Eco-scenario (Figure 3).

When compared to the EU-27 total electricity consumption¹⁰ projected for the year 2020, the net energy savings can amount to 2.8 % (111.3 TWh) of EU-27 total electricity consumption in the BAU scenario and 53.4 % (2,127 TWh) in the Eco-scenario.

In order to provide an order of magnitude for putting the results in perspective with the EU policy target on primary energy reduction, the net savings can be expressed in terms of equivalent primary energy required, to produce the same amount of TWh of electricity. Such equivalence (the primary energy required to produce 111.3 TWh and 2,127 TWh of electricity is 27.9 Mtoe and 533.9 Mtoe respectively¹¹) indicates that,

⁹ i.e. savings enabled by ICT applications in other sectors to which is subtracted the energy consumption of the ICT sector itself

¹⁰ This comparison is realised only to provide an order of magnitude, however, it should be noted that the energy savings enabled by ICT do not only refer to electricity savings (e.g. HVAC systems in buildings are based on different types of energy : oil, gas, etc).

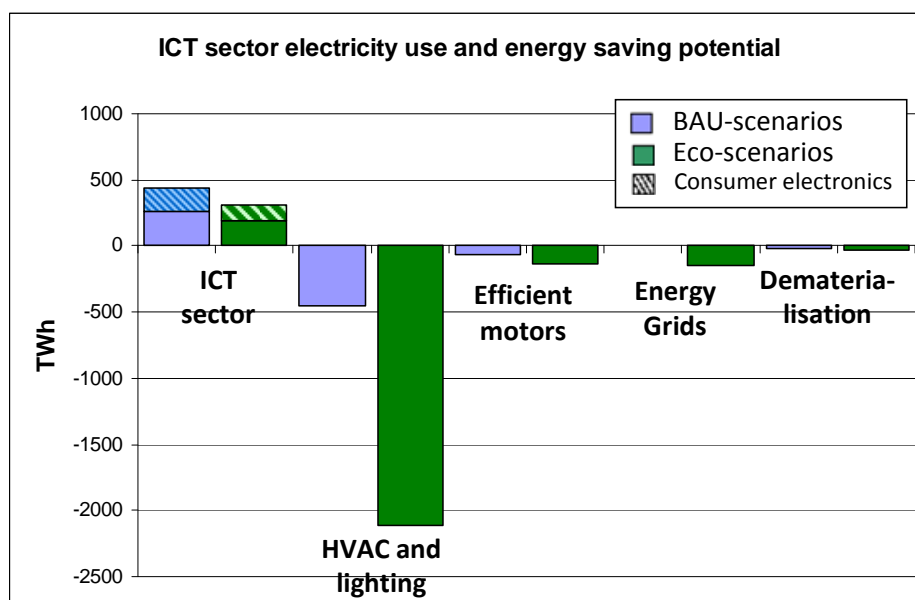
¹¹ Such equivalence was calculated using the conversion factors from the EcoReport tool which is the official life cycle analysis tool developed in the framework of the Eco-Design Directive 2005/32/EC i.e. 1MWh electricity = 10,500 MJ primary energy = 0.251 toe primary energy

when compared to the total EU-27 projected primary energy consumption¹², the net savings could represent between 1.7 % (BAU) and 32.5 % (Eco).

Taking out the consumer electronics from the total electricity consumption represented by the ICT sector (i.e. TVs, mobile devices, audio systems, VHS/DVD equipment, and set-top boxes, which are assumed to play a less important role in supporting the enabling effects of ICT technologies) the net energy savings were estimated to 285.3 TWh in a BAU-scenario and 2,246.6 TWh in an Eco-scenario.

However, these numbers should be interpreted with care as they only suggest an order of magnitude (i.e. all the energy savings do not refer to the electricity savings).

Figure 3: ICT electricity use and energy saving potential in other sectors (EU-27)

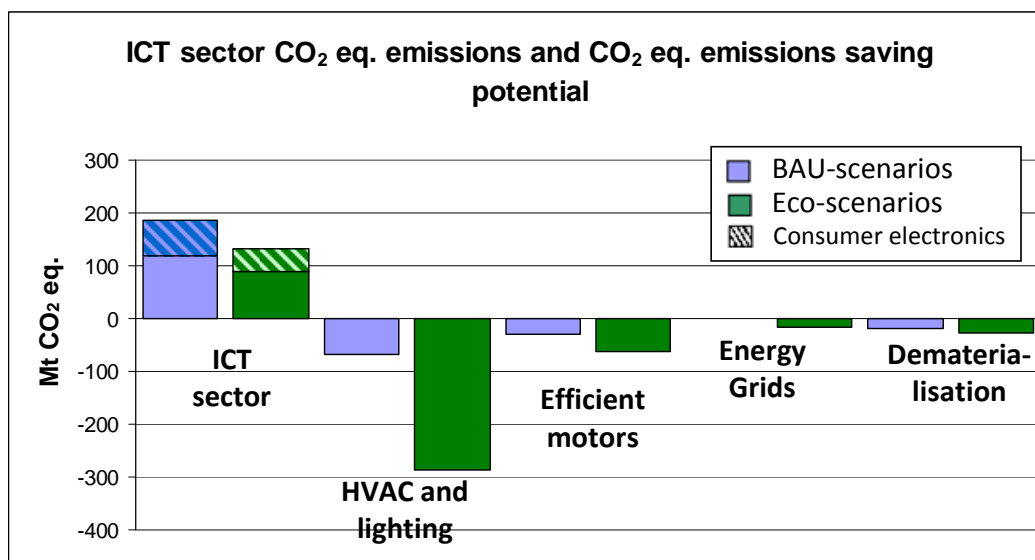


In terms of CO₂ eq. emissions, the study finds that the net savings are only positive in the Eco-scenario and amount to 4.6 % of EU-27 CO₂ eq. emission level of 1990¹³ (see Figure 4). Taking out the CO₂ emissions from consumer electronics, the net savings in the Eco-scenario reach 5.4 % of EU-27 CO₂ eq. emission level of 1990.

¹² Forecasted primary energy consumption for EU 27 in 2020 is 1634.3 Mtoe according to the European Commission Directorate-General for Energy and Transport: European Energy and Transport - Trends to 2030, update 2007, Belgium 2008

¹³ 5572.2 Mt CO₂ eq. According to the EEA *Annual European Community greenhouse gas inventory 1990–2006 and inventory report 2008 Submission to the UNFCCC Secretariat*, May 2008

Figure 4: ICT sector CO₂ eq. emissions and CO₂ eq. emissions saving potential (EU-27)



To conclude, the study shows that in the Eco-scenario, the savings could represent over 7 times the ICT sector's direct impacts in terms of energy and about 3 times in terms of CO₂ emissions.

In the BAU scenario, the savings are found to be slightly higher than ICT sector's footprint in terms of energy consumption (savings represent 1.26 times the ICT sector electricity consumption). However, in terms of CO₂ eq. emissions, ICT sector's emissions are estimated to be higher than the CO₂ savings (1.7 times higher).

The necessary assumptions¹⁴ made in order to convert the energy savings into CO₂ equivalent emission savings lead to an overestimation of the CO₂ emissions and therefore the results in terms of CO₂ equivalent emission should be interpreted with care. Nevertheless, the estimates still provide an order of magnitude.

The results illustrate that key actions are needed to achieve the Eco-scenario. They are suggested in sector-specific recommendations for each of the three ICT effects on energy efficiency analysed in study. The recommendations provided are covering the following aspects:

- Development of standardised methods to measure environmental performance of ICT based products and services

¹⁴ Throughout the 2005-2020 period, a fixed CO₂ equivalent emission factor was assumed and used for converting electricity use into CO₂ equivalent emissions (please note that this approach is also the approach adopted in the various EuP preparatory studies conducted in the framework of the Directive 2005/32/EC on Eco-design). However, the evolution of the energy sector forecasts an increase in renewable energy and less fossil fuel based energy sources which will decrease the emission factor in the future. Also business lead initiatives in the ICT sector to promote the use of renewable energy were not taken into account (further detail in section related to the definition of conversion factors used). Therefore the results in terms of CO₂ equivalent emissions should be interpreted with care.

- Improvement and monitoring of statistical data to make efficiency and effectiveness a reality
- Development of appropriate incentives to encourage the take up of energy efficient technologies and practices
- Promotion of public-private partnerships in energy efficiency
- Provide Information and guidelines
- Development of internet connectivity to facilitate ICT-based solutions
- Identification of R&D needed in ICT and further support for R&D together with Innovation actions
- Development of open standards and interoperability

Definition of conversion factors used

Throughout the study, different units¹⁵ are used to express quantities of energy: electricity is mainly expressed in kWh, but other units such as toe (ton oil equivalent) and MJ (Mega Joule) are used. The following conversion factors between these units are used¹⁶:

$$1 \text{ toe} = 11.63 \text{ MWh} = 41,868 \text{ MJ}$$

The energy (including electricity) generation produces greenhouse gases emissions. For example CO₂ equivalent (eq.) emissions generated by 1 kWh of electricity produced can be calculated and quantities of electricity can be converted in quantities of CO₂ equivalent. In the same fashion mix of energies (electricity, gas, etc.) can be converted in CO₂ equivalent emissions. Conversion factors are presented in table below.

The primary energy necessary to produce electricity is also included in the table. Primary energy refers to energy that exists in naturally occurring form, such as coal, before being converted into a more convenient end-use form of energy (i.e. electrical energy).

Some reference data on EU wide (both EU 25 and 27) energy consumption figures is also provided in section 1.2.1 which will be used as reference for measuring the relative significance of the ICT sector and of the ICT-enabled energy savings.

¹⁵ Reminder : kilo (k) 10³/mega (M) 10⁶/giga (G)10⁹/tera (T) 10¹²/peta (P) 10¹⁵

¹⁶ From the International Energy Agency conversion webpage
(<http://www.iea.org/Textbase/stats/unit.asp>)

Table 2: Conversion Electricity - Primary Energy - CO₂ equivalent emissions

Parameter	Energy Quantity	Primary energy equivalent	CO ₂ eq. emissions	Source	Comment
Electricity	1 kWh	10.5 MJ	0.4582 kg CO ₂ eq.	EuP EcoReport tool (official Life Cycle Analysis tool developed in the context of the EuP Directive 32/2005/EC)	used throughout the 2005-2020 period
Electricity	1 MWh	10,500 MJ (=0.251 toe)	458.2 kg CO ₂ eq.		
Electricity	11.63 MWh (=1 toe)	122,115 MJ	5.3 t CO ₂ eq.		
Electricity	3.99 MWh	41,868 MJ (=1 toe)	1.82 t CO ₂ eq.		
Residential sector energy use (electricity, gas, etc.)	1 toe	-	1.44 t CO ₂ eq.	Carbon intensity of the residential sector for the year 2020 from European Commission Directorate-General for Energy and Transport: European Energy and Transport - Trends to 2030, update 2007, Belgium 2008 (annex 2 - carbon intensity of the residential sector)	used in Task 2 (subtask 2.1)
Service sector energy use (electricity, gas, etc.)	1 toe	-	1.28 t CO ₂ eq.	Carbon intensity of the service sector for the year 2020 from European Commission Directorate-General for Energy and Transport: European Energy and Transport - Trends to 2030, update 2007, Belgium 2008 (annex 2 - carbon intensity of the service sector)	used in Task 2 (subtask 2.1)

0. Introduction

Information and Communication Technologies (ICT) can be defined as the use of telecommunications equipment, electronic computing equipment and respective software to convert, store, protect, process, transmit and retrieve mostly digitalized information. Information Technology refers to the hardware, data processing equipment, communications equipment, middleware, software, and related services.

This study assesses the potential contribution of ICT-based technologies to improve the energy efficiency of the EU economy, both by investigating how the ICT sector can reduce its own footprint, and more importantly by focusing on how the application of ICTs to different areas of industrial and business activities can result in energy savings.

Primary, secondary, and tertiary environmental effects associated to ICTs are covered by the present study respectively in tasks 1 (focus on primary effects); task 2 and 3 (focus on secondary and tertiary effects). Primary effects refers to the environmental impact of the ICT equipment and infrastructure, secondary effects relate to environmental impacts caused by the application of ICT based technologies in other sectors e.g. manufacturing, and tertiary effects refer to the ones caused by new consumption patterns and habits emerging from the use of ICTs e.g. reduced need to commute through e-work.

The indicator used to quantify the improvement potential of ICT devices is the amount of energy saved in kWh and toe¹⁷ (secondary energy as opposed to primary energy¹⁸) converted in CO₂ equivalent.

The main conversion factor¹⁹ used to convert the energy (electricity) in terms of CO₂ equivalent is the conversion factor for electricity. Savings of electricity were converted into CO₂ emissions savings using the conversion factor from the EcoReport tool which is the official life cycle analysis tool developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh). This factor was assumed to be constant throughout the period under review (2005-2020). This assumption leads to overestimating the CO₂ equivalent emissions related to electricity use, as the future of the electricity grid forecasts an increase in renewable energies which should therefore

¹⁷ The energy savings are expressed in toe, as they do not solely refer to electricity savings (commonly expressed in kWh) but can include savings of gas, or other sources of energy (e.g. in the buildings sector). Toe : Tonne Oil Equivalent. 1 toe = 11.63 MWh= 11.63 x 10³ kWh (IEA conversion website) <http://www.iea.org/Textbase/stats/unit.asp>

¹⁸ Except for the Energy Grid sector (subtask 2.3) the savings are expressed in terms of primary energy in order to consider the benefits from more efficient electricity solutions

¹⁹ Other conversion factors were used when electricity was not the only source of energy on which savings were enabled and are presented in the study

reduce the emission factor. As such the estimates in CO₂ equivalent emissions should be interpreted with care, keeping in mind that they are overestimated. Nevertheless they still provide good orders of magnitude.

The study also covers technological aspects which build the base for functional benefit of ICT and technical solutions from a system point of view allowing indicating the interaction of ICT infrastructure, end-user devices and related use patterns. This includes measures regarding the energy efficient design of products, green procurement, and promotion of user awareness.

A balanced assessment of the benefits and burdens related to the ubiquitous application of ICT is needed for this study. Energy efficiency is directly linked to the development and application of ICT solutions in order to generate a positive ratio between their benefits in improving the socio-environmental situation and the burdens related to their manufacturing and use which is mainly energy consumption. The study elaborates on the problems related to this issue. In conjunction with this given task we discuss how we define benefits and burdens related to ICT and what practical parameters are the best to assess them. In the past years a tedious scientific and political discussion has started about sustainability assessment methodologies and indicators. Although this research is essential in the long term, at present time we should give it a second priority and focus on practical activities such as the assessment of energy efficiency as an important first step.

Against that background, a holistic view is taken on ICT application, devices, and use patterns under the current socio-economic situation in the European Union. This includes not only the technical situation but also the means of influence on a political, economical, and societal level. As a result, we will provide technical facts which support a better understanding of the options and challenges related to a pervasive application of ICT in all areas of industrial, public and private life.

Throughout the study, conclusions were derived on the basis of available information and suitable recommendations were made, for example, concerning the needed directly supporting measures (e.g. supported R&D programs) and policy measures.

The study consists of three main tasks and of a concluding section (task 4):

- **Task 1: The ICT Sector – State of the art and future trends**, which defines and assesses the total electricity consumption of ICT equipment during the use phase (until 2020)
- **Task 2: Discussion and quantification of ICT applications enabling energy efficiency – 2020 outlook**, which provides data on the current status of energy consumption of different sectors (buildings, industrial equipment and automation, energy grids) and the potential of ICT application in support of higher energy efficiency (until 2020)
- **Task 3: Discussion and quantification of ICT applications enabling energy efficiency through dematerialisation– 2020 outlook**, which provides data on the potential of ICT

application in support of higher energy efficiency through dematerialisation of society and in management and process support (until 2020)

- **Task 4: Conclusions**, which summarises and compares the potential of higher energy efficiency enabled by ICT application of the different sectors studied.

In Task 1, both a Business-as-Usual (BAU) scenario and an Eco-scenario were used to project the evolution of the sector until 2020. The BAU-scenario projects a situation in continuity with the current status (reference year 2005) considering the existing market trends, technology trends and legislations. The Eco-scenario considers a more optimistic scenario where the uptake of energy efficient appliances is higher and where policy and voluntary measures support this accelerated penetration of efficient ICT devices.

In order to analyse and estimate the potential that ICT-based applications can provide to improve the energy efficiency (Task 2 and 3), various domain-dependant scenarios were developed:

- Baseline scenarios (reference scenarios): mainly based on literature data, these scenarios do not take into account the increase in the use of ICT-based applications. These baseline scenarios are the reference against which to evaluate the alternative scenarios²⁰.
- Business-as-Usual scenarios (BAU): which assume that continuity is maintained considering the current situation and trends
- Eco-scenarios: which assume that there is a push for ICT-based energy efficient solutions.

In addition, where no solid quantified data could be obtained, “low”, “medium” and “high” hypotheses were used in order to provide a reasonable range of data and order of magnitude.

²⁰ In Subtask 2.3. on energy grids, we assume that the baseline scenario is the same as the BAU scenario, therefore no baseline scenario was used

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1. The ICT sector – State of the art and future trends

1.0. INTRODUCTION

Information and Communication Technologies (ICT) can affect the natural environment directly or indirectly and such effects can be of following three types:

- First order effects include the direct environmental impacts caused by ICT equipment during its life cycle viz. production, use phase, and end-of-life (reuse, recycle, or final disposal).
- Second order effects relate to the application of ICT in other sectors, thus causing an indirect impact on the environment e.g. the environmental impact of a production process can be different when an ICT technology is applied to manage or monitor the process.
- Third order effects are macro-level indirect effects resulting from structural and behavioural changes and adaptation to the ICT services as a part of everyday life and business.

This section focuses on the **first order effects** of the ICT sector, which are influenced by the market growth, technological trends (e.g. miniaturisation of ICT devices), and legislations development for the ICT sector itself. The second and third order effects can be assumed to have a much higher potential impact on the environment, because today ICT is applied in almost every sector²¹. These indirect effects will be discussed in more detail in the later tasks of this study. While covering the first order effects, our focus **will be on the energy (electricity) consumption during the use phase. The amount of waste generated at the end-of-life, and the energy and raw material requirements in the production phase** will also be analysed.

The objective of Task 1 is to **define and assess the total electricity consumption of ICT during the use phase of ICT equipment**. This assessment will provide the basis for analysing further the potential of the ICT to improve the energy efficiency of the European Union and reduce greenhouse gas emissions in various applications and industrial sectors.

Task 1 consists of four subtasks:

Subtask 1.1 – Definition of ICT – common market segmentation and specific working structure

²¹ Hilty and al. *The future impact of ICT on environmental sustainability. Fourth Interim Report. Refinement and quantification*. Institute for Prospective Technological Studies (IPTS) 2004

This subtask first defines the scope of the ICT sector being analysed in terms of ICT equipments considered e.g. ICT devices and ICT infrastructure.

Subtask 1.2 – Basic economic data

This section provides the necessary background data to estimate the overall electricity consumption of the ICT sector in the EU.

Subtask 1.3 – Electricity consumption of the ICT sector – Outlook until 2020

This subtask presents an analysis of the evolution of ICT devices and of the ICT infrastructure in terms of electricity consumption at the EU level until 2020.

A business-as-usual scenario is presented taking into account existing policy frameworks, voluntary initiatives, and future trends (policy, market, and technology). This is followed by the development of an “Eco-scenario” assuming that potential improvements in the energy efficiency of ICT devices will be realised in the future. The analysis is presented for each ICT device and each type of ICT infrastructure and then summarised for the ICT sector as a whole. Key obstacles for future energy efficiency improvement are identified and recommendations are made on the potential needs for future research, voluntary programs, or policy actions.

Subtask 1.4 – Assessment of the social impacts and environmental effects

This subtask assesses the business opportunities created by the development of the ICT sector and the other environmental effects (i.e. environmental impacts of the manufacturing and end-of life phase of ICTs) of ICT devices.

1.1. DEFINITION OF ICT – COMMON MARKET SEGMENTATION AND SPECIFIC WORKING STRUCTURE

In general, the term Information and Communication Technology (ICT) relates to electronic computing equipment and the related software to convert, store, protect process, transmit, and retrieve mostly digitised information. Against this broad understanding of the term ICT, a clearer definition of the ICT sector is needed for the purpose of this study, which is in line with commonly used market classifications. Further, in order to assess the energy consumption of the ICT sector, a more detailed definition is required which identifies the type of products that can be included in the broad “ICT equipment” category.

1.1.1. INTERNATIONAL STANDARD INDUSTRIAL CLASSIFICATION

The International Standard Industrial Classification (ISIC) provides a standard base for the definition of the ICT. The following table shows the 4-digit-level of ISIC classification of the ICT sector.

Table 3: ISIC classification of the ICT sector

ISIC (4-digit)	Product and industry scope of ICT classes
3000	Office, accounting and computing machinery
3130	Insulated wire and cable
3210	Electronic valves and tubes and other electronic components
3220	Television and radio transmitters and apparatus for line telephony and line telegraphy
3230	Television and radio receivers, sound or video recording or reproducing apparatus, and associated goods
3312	Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process equipment
3313	Industrial process control equipment
5150	Wholesaling of machinery, equipment and supplies
6420	Telecommunications
7123	Renting of office machinery and equipment (including computers)
72	Computer and related activities

The ISIC categorisation provides a scope for ICT related products and business sectors. This classification supports the analysis of market statistics and the allocation of typical market segments, but these product segments are still quite general and not adapted for investigating the energy consumption of the ICT sector.

1.1.2. EUROPEAN INFORMATION TECHNOLOGY OBSERVATION

The European Information Technology Observation (EITO) structures ICT in a more business oriented way. Following product segmentation is used by EITO in their annual market analyses:

- Computer hardware
- End-user communications equipment
- Telephone sets and other terminal equipment
- Mobile telephone sets
- Office equipment
- Data communication and network equipment

- PBX²² and key systems
- Packet switching and routing equipment
- Transmission and switching
- Cellular mobile infrastructure
- Other data communication and network equipment
- Software products
- IT services
- Carrier services²³
- Fixed voice telephone services
- Fixed data services
- Mobile telephone services

The EITO segmentation is useful for defining various subcategories of ICT according to hardware (equipment), software and services. In order to extend this useful approach for defining the products falling under ICT, a working ICT definition is proposed for the purpose of this study.

1.1.3. WORKING DEFINITION OF ICT

For the purpose of this study, the ICT sector can be divided in three levels:

- Technology – The materials, processes, and technical principles that creates the basic hardware elements (electronic, photonic, mechanic component layer)
- Equipment – The combination of basic hardware elements and software which creates a functional system or device (product layer)
- Services – System-based applications of hardware and software with content (content layer)

■ Technology

In terms of technology, a general distinction can be made between “information technology” and “communication technology”. The “information technology” covers basically hardware elements such as active and passive electronic components and

²² Private Branch eXchange (PBX) is a telephone exchange that serves a particular business or office, as opposed to one that a common carrier or telephone company operates for many businesses or for the general public.

²³ In telecommunication, a carrier system is a multichannel telecommunications system in which a number of individual circuits (data, voice, or combination thereof) are multiplexed for transmission between nodes of a network.

micro-systems. Under “communication technology”, we intend to cover the principle data transmission and network technologies. The distinction of basic hardware elements (technology) helps to identify the functional spectrum of ICT. Following structure details the elements at the **Technology** level:

- Information technology
 - Data processing (e.g. main/specific processor ICs such as CPUs²⁴, DSPs²⁵, GPUs²⁶)
 - Data storage (e.g. semiconductor IC, optical disc, magnetic hard disk)
 - Data input (e.g. optical, acoustical, temperature, acceleration, pressure sensors [typical micro-systems])
 - Data output (e.g. optical [displays/light projection], acoustical [speakers], Micro-electro-mechanical [MEMS])
- Communication technology
 - Wired telephony (e.g. Point to point telecommunication ISDN, ADSL, IP-Telephony)
 - Radio broadcast (e.g. TV and radio signal transmission)
 - Mobile telephony (e.g. GSM, GPRS, UMTS)
 - Wired data transmission (e.g. the physical, data link, network, transport layer of the internet or local area networks)
 - Wireless-LAN and radio frequency [RF]technology (e.g. Wi-Fi, Bluetooth, ZigBee)

■ Equipment

Under the term equipment we cover “end-user-devices” as well as “infrastructure” that consist of both hardware and software elements. The equipment level is the main level at which the energy consumption of ICT will be investigated. Software products such as system or application programs are allocated to the last level of ICT (service level) because they are usually connected to a specific content.

The following structure details the elements of the **Equipment** level:

- ICT end-user devices
 - Computers and peripherals (e.g. server, individual computer, game console, laptop, office imaging equipment)

²⁴ CPU, Central Processing Unit

²⁵ DSP, Digital Signal Processor

²⁶ GPU, Graphics Processing Unit

- Digital Data recorder-storage-player devices (e.g. DVD, HDD, USB memory, MP3)
- Modems (e.g. high and low speed network interfaces)
- Phones and multimedia mobiles (e.g. normal and cordless phones, mobile phones)
- Fax machines (e.g. telephone or MFD based)
- TV and peripherals (e.g. TV, STB, antenna, satellite dish)

The boundary between ICT equipment and Consumer Electronics (CE) is very difficult to set. For example, triple play set-top boxes (allowing internet access and telephony, as well as access to digital TV services) are at the convergence of ICT and CE. For the purpose of this study, it was assumed that the ICT sector includes the consumer electronics defined by: TVs, Mobile devices, Audio systems, VHS/DVD equipment and Set-top boxes. Consumer electronics are more likely for casual use and entertainment rather than professional use and are foreseen to play a less significant role in the development of ICT-based energy saving solutions

- ICT infrastructure

- Server and data centres (e.g. internet servers)
- Wired core telecom networks (e.g. copper or optical fibre lines, network router/switches)
- Cellular phone network (e.g. GSM or UMTS base transceiver stations [nodes], main switches, antenna systems)
- Wireless Local Area networks (e.g. Wi-Fi, Bluetooth, ZigBee nodes and antenna)
- Radio/TV broadcast equipment (e.g. radio relays, directorial radio antennas)
- Micro systems

- Services

The final level of ICT is defined by the use or application of products including the respective hardware, software, and individual media content. The ICT services provided through the utilisation of computers and networks form the basis for dematerialisation of processes and objects. The technology and equipment platforms for ICT services are interrelated and can be structured e.g. according to necessary infrastructure.

The following structure details the elements at the Services level:

- Computer-based

- Data-processing
- Media-processing
- Computer aided design (CAD)

- Computer simulations
- Telecom-based
 - Tele-working
 - Tele-shopping
 - Tele-conferencing
- Internet-based
 - E-business
 - E-commerce
 - E-government
 - E-learning
- GPS-based
 - Navigation systems
 - Traffic control systems
 - Security systems
 - Rescue systems

1.2. BASIC ECONOMIC DATA

This section presents the basic reference data which will be used further in the study. The basic electricity consumption data provides the information in the European context in order to provide a scale of comparison when assessing the electricity footprint of the ICT sector. Also, factors which might externally influence the growth of the ICT sector are presented: European population growth, number of households, and electricity price.

1.2.1. BASIC ELECTRICITY CONSUMPTION DATA

■ EU total electricity consumption data

EUROSTAT estimates the **EU 27 total electricity consumption for the year 2005 to be 2,756 TWh**. This can be divided into²⁷

- Households & services: 1,525 TWh/a (56.4 %)

²⁷ EuroStat, data available at:

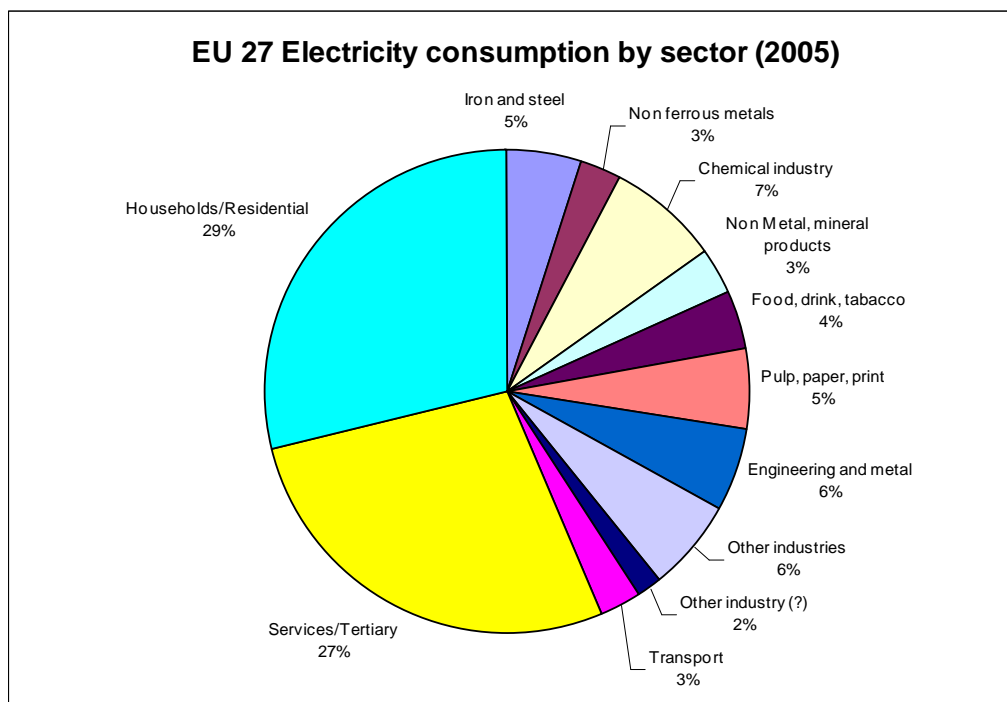
http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=Yearlies_new_environment_energy&root=Yearlies_new_environment_energy/H/H2/H24/ebc20240

- Industry: 1,094 TWh/a (40.9 %)
- Transport: 72 TWh/a (2.7 %)

A more detailed electricity distribution is presented in Figure 5.

In EU 25, the total electricity consumption amounts to 2,691 TWh for the year 2005.

Figure 5: EU 27 Electricity consumption (EuroStat)



■ Future trends in electricity consumption in the EU

The Directorate General Energy and Transport²⁸ provides energy trends until 2030 for the European Union (Table 4).

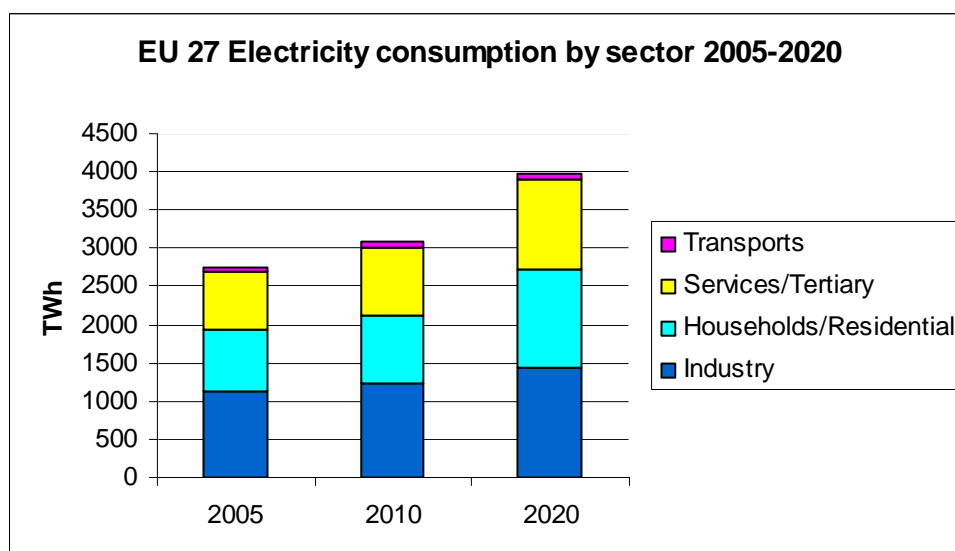
²⁸ DG TREN Trends 2030 update 2005

http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2005/energy_transport_trends_2030_update_2005_en.pdf

Table 4: Sector-wise electricity requirement in EU 25²⁹

	TWh				
	1990	2000	2010	2020	2030
Industry	921.5	1042.2	1199.9	1318.5	1396.5
Residential	568.7	694.6	880.5	1097.5	1272.3
Tertiary	502.7	651.9	856.2	1032.4	1144.4
Transports	59.1	68.8	78.7	73.9	71.0
Energy sector	268.7	267.9	298.8	312.2	317.2
Trans. and distr. Losses	160.4	200.3	195.1	195.9	190.7
(Net imports)	25.4	24.9	26.0	24.7	25.6
Electricity generation	2455.7	2900.8	3483.2	4005.8	4366.6
EU-15	2138.9	2576.5	3082.7	3484.7	3735.4
NMS	316.7	324.3	400.4	521.0	631.2
	Annual Growth Rate (%)				
	90/00	00/10	10/20	20/30	00/30
Industry	1.2	1.4	0.9	0.6	1.0
Residential	2.0	2.4	2.2	1.5	2.0
Tertiary	2.6	2.8	1.9	1.0	1.9
Transports	1.5	1.4	-0.6	-0.4	0.1
Energy sector	0.0	1.1	0.4	0.2	0.6
Trans. and distr. Losses	2.2	-0.3	0.0	-0.3	-0.2
(Net imports)	-0.2	0.4	-0.5	0.4	0.1
Electricity generation	1.7	1.8	1.4	0.9	1.4
EU-15	1.9	1.8	1.2	0.7	1.2
NMS	0.2	2.1	2.7	1.9	2.2

Figure 6: Estimates based on data from DG TREN³⁰ (above) and EUROSTAT



■ Future worldwide trends in energy consumption

Table 5 provides an indication of future worldwide trends in energy consumption.

²⁹ Electricity consumption in refineries as well as on-site auto-consumption of electricity in the power generation sector is included in the energy sector. Source : DG TREN

http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2005/energy_transport_trends_2030_update_2005_en.pdf

³⁰ http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2005/energy_transport_trends_2030_update_2005_en.pdf

Table 5: European and Worldwide energy trends³¹

Regional indicators	1990	2007 (Estimated)	2020 (Projected)	Growth 2007-2020 (percent change)
European Union (EU 27)				
GDP (1000 million Euros)	7,359	10,248	13,825	35%
Energy (1000 million toe)	1.65	1.83	1.97	8%
Emissions (Mt of CO ₂)	4,010	3,967	4,091	3%
Intensity (toe/ Million Euro)	224	178	142	-20%
United States				
GDP (1000 million Euros)	5,394	8,860	12,949	46%
Energy (1000 million toe)	2.13	2.62	2.98	14%
Emissions (Mt of CO ₂)	4,989	6,102	6,944	14%
Intensity (toe/ Million Euro)	396	295	230	-22%
World Totals				
GDP (1000 million Euros)	18,062	29,116	43,840	51%
Energy (1000 million toe)	8.75	11.92	15.30	28%
Emissions (Mt of CO ₂)	21,246	28,555	36,854	29%
Intensity (toe/ Million Euro)	485	409	349	15%
<p>Note: Gross Domestic Product (GDP) values are in 1000 million of year 2000 Euros, total primary energy use is in 1000 million tonnes of oil equivalent, greenhouse gas emissions are in million tonnes of carbon dioxide, and energy intensity is expressed as tonnes of oil equivalent (toe) per 1 million. In the last column, the percentages show the projected change over the period 2007 through 2020.</p> <p>Source: ACEEE calculations for this table are drawn from a variety of published statistics, including European Energy and Transport: Trends to 2030 – Update 2005, European Commission, Directorate-General for Energy and Transport, Brussels, May 2006; World Energy Outlook 2006, International Energy Agency, Paris France; and <i>International Energy Outlook 2006</i>, Energy Information Administration, Washington, DC. Owing to the differences among various information sources, these numbers should be viewed only as indicative patterns rather than as absolute values.</p>				

1.2.2. INFLUENCING FACTORS

The energy consumption is also driven by demographic factors and economical factors.

³¹ Advanced Electronics and Information Technologies: The Innovation-Led Climate Change Solution. American Council for an Energy-Efficient Economy (ACEEE) 2007

1.2.2.1 Population and number of households

Table 6: EUROSTAT projections of EU 25 population in millions³²

(at 1 January, million)

	2005	2010	2015	2020
EU-25	458.5	464.1	467.3	469.3
EU-15	384.5	390.7	394.7	397.5
Euro area	310.2	315.1	317.9	319.4
Belgium	10.4	10.6	10.7	10.8
Czech Republic	10.2	10.1	10.0	9.9
Denmark	5.4	5.5	5.5	5.5
Germany	82.6	82.8	82.9	82.7
Estonia	1.3	1.3	1.3	1.2
Greece	11.1	11.3	11.4	11.4
Spain	42.9	44.6	45.3	45.6
France	60.2	61.5	62.6	63.6
Ireland	4.1	4.3	4.6	4.8
Italy	58.2	58.6	58.6	58.3
Cyprus	0.7	0.8	0.8	0.9
Latvia	2.3	2.2	2.2	2.1
Lithuania	3.4	3.3	3.3	3.2
Luxembourg	0.5	0.5	0.5	0.5
Hungary	10.1	10.0	9.8	9.7
Malta	0.4	0.4	0.4	0.5
Netherlands	16.3	16.7	17.0	17.2
Austria	8.1	8.3	8.4	8.4
Poland	38.1	37.8	37.4	37.1
Portugal	10.5	10.7	10.8	10.8
Slovenia	2.0	2.0	2.0	2.0
Slovakia	5.4	5.3	5.3	5.3
Finland	5.2	5.3	5.4	5.4
Sweden	9.0	9.2	9.4	9.6
United Kingdom	59.9	60.9	61.9	62.9
Bulgaria	7.7	7.4	7.1	6.8
Romania	21.7	21.3	20.9	20.3

Table 7: Projection of number of households until 2025 (EUROSTAT)³³

Total number of households (millions) and average number of persons per household

	Number of households							Average number of persons per household						
	1995	2010			2025			1995	2010			2025		
		IS	BS	FS	IS	BS	FS		IS	BS	FS	IS	BS	FS
EU-15	147.9	165.5	165.2	164.7	171.4	176.0	180.3	2.48	2.21	2.30	2.40	2.05	2.17	2.30
Belgium	4.0	4.6	4.5	4.5	4.7	4.8	4.9	2.49	2.19	2.29	2.40	2.05	2.19	2.33
Denmark	2.4	2.6	2.6	2.5	2.6	2.8	2.8	2.10	1.98	2.09	2.19	1.86	1.99	2.12
Germany	36.6	39.8	39.8	39.8	39.8	41.2	42.5	2.20	2.03	2.12	2.23	1.92	2.02	2.15
Greece	3.8	4.3	4.4	4.4	4.5	4.7	4.8	2.71	2.40	2.49	2.55	2.24	2.36	2.45
Spain	12.1	14.7	14.7	14.6	15.8	16.1	16.4	3.21	2.62	2.73	2.86	2.32	2.47	2.65
France	23.4	27.0	26.7	26.3	28.7	29.0	29.3	2.43	2.17	2.26	2.37	2.01	2.14	2.29
Ireland	1.1	1.4	1.4	1.4	1.6	1.6	1.6	3.09	2.50	2.63	2.77	2.24	2.39	2.59
Italy	20.5	22.5	22.9	23.2	22.4	23.6	24.5	2.73	2.41	2.46	2.51	2.22	2.30	2.39
Luxembourg	0.16	0.19	0.19	0.19	0.21	0.23	0.24	2.53	2.29	2.42	2.55	2.09	2.25	2.42
Netherlands	6.4	7.3	7.2	7.2	7.8	8.0	8.2	2.36	2.15	2.27	2.39	1.98	2.13	2.26
Austria	3.1	3.5	3.5	3.5	3.7	3.8	3.9	2.51	2.22	2.34	2.46	2.06	2.21	2.37
Portugal	3.3	3.9	3.9	3.9	4.1	4.3	4.4	2.95	2.56	2.65	2.75	2.32	2.46	2.59
Finland	2.4	2.6	2.6	2.6	2.6	2.7	2.8	2.11	1.94	2.02	2.11	1.86	1.95	2.07
Sweden	4.2	4.5	4.4	4.4	4.7	4.8	4.9	2.10	1.96	2.06	2.17	1.85	2.00	2.14
United Kingdom	24.2	26.8	26.6	26.3	28.1	28.6	29.1	2.38	2.16	2.23	2.34	2.02	2.11	2.26

Note: IS: individualisation scenario, BS: baseline scenario, FS: family scenario

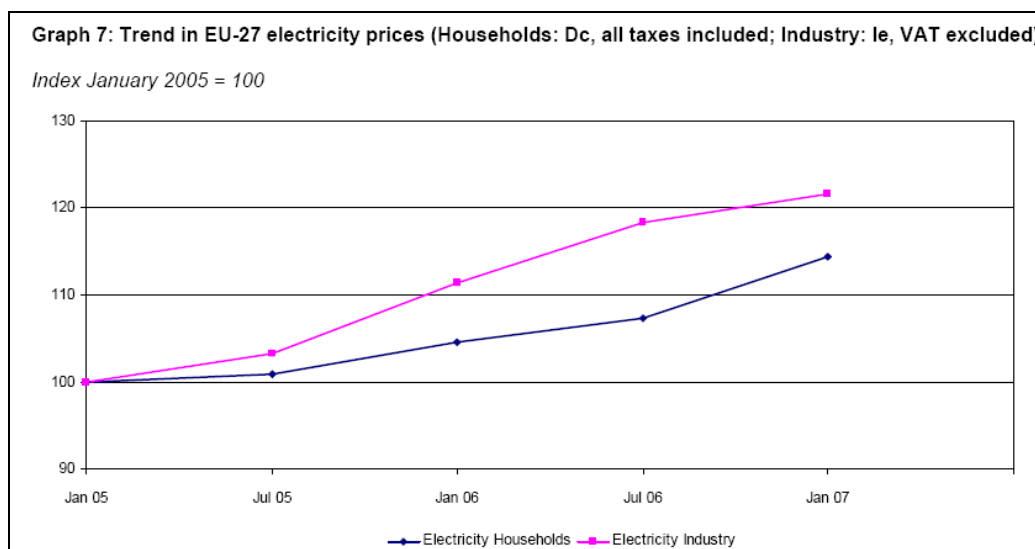
³² http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-CD-06-001-01/EN/KS-CD-06-001-01-EN.PDF

³³ EuroStat: http://www.eds-destatis.de/en/downloads/sif/nk_03_24.pdf

1.2.2.2 Evolution of electricity price

The current trend toward more expensive electricity will certainly affect the management and use of electricity in Europe (Figure 7)

Figure 7: Trends in EU-27 electricity prices³⁴



1.2.3. STRUCTURE FOR OUTLOOK SCENARIO

In the next section 1.3. scenarios of the evolution of the ICT electricity consumption are presented, with data for the following reference years:

- 2005
- 2010
- 2020

Both a business-as-usual scenario (BAU), mostly built as an extrapolation of the 2005 situation, and an Eco-scenario reflecting the improvement potential of the IT equipments are also developed. Further details are provided in the next section.

1.3. ELECTRICITY CONSUMPTION OF THE ICT SECTOR – OUTLOOK UNTIL 2020

This sub-section provides an assessment regarding the current share of ICT equipment in terms of total EU 25 energy consumption. The year 2005 has been selected as reference point due to the availability of data. The other chosen references years are 2010 and 2020. The annual electricity consumption during use phase is taken as an

³⁴ EUROSTAT Statistics in focus 2007

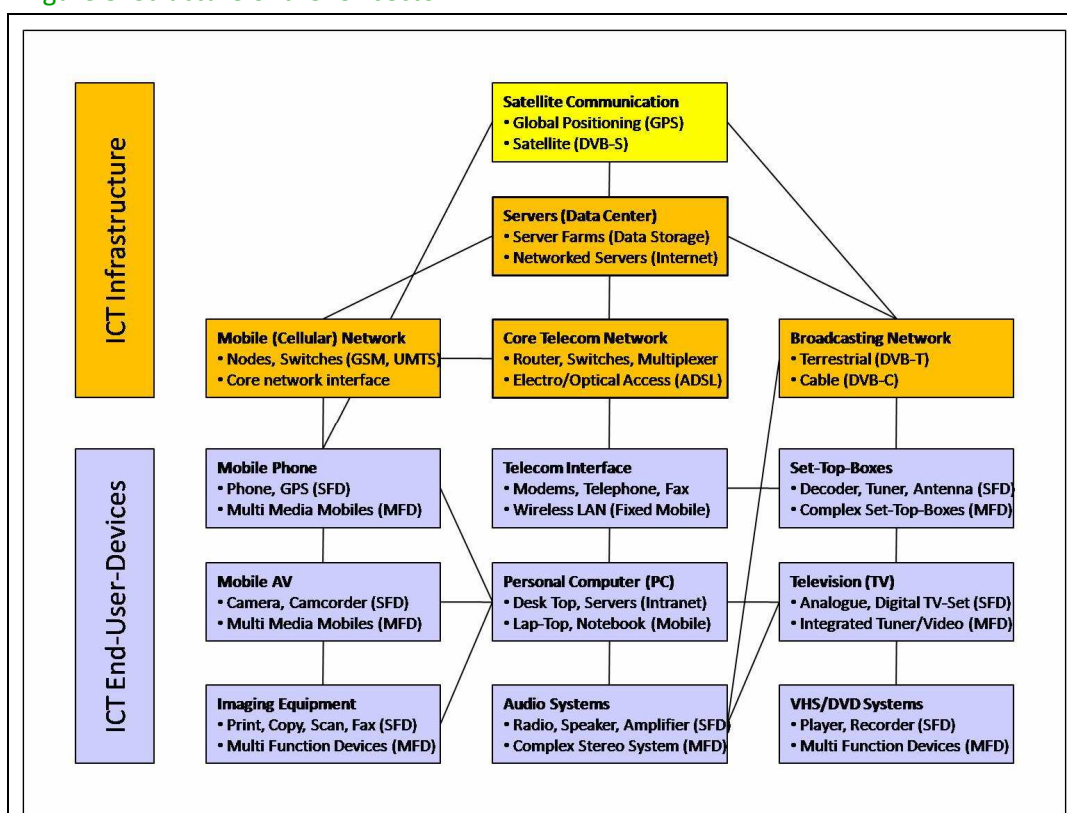
http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-080/EN/KS-SF-07-080-EN.PDF

indicator for the energy impact of the ICT sector. This indicator is relevant as the use phase of ICT equipments has been proven to be the most significant in terms of environmental impacts in their life cycle, due to the electricity use³⁵. This will be further discussed in section 1.4.1.

As discussed earlier, ICT equipment can be of following two types (Figure 8):

- ICT end-user-device
- ICT infrastructure

Figure 8: Structure of the ICT sector



This section projects the development trajectories in terms of stock (in million units) and per unit electricity consumption (in kWh/year per unit) of ICT devices and of ICT infrastructures both in a business-as-usual (BAU) scenario and in an Eco-scenario which uses more optimistic assumptions on the improvement of the energy efficiency of the ICT sector (both devices and infrastructure).

The BAU scenario takes into account existing and upcoming policies, existing and upcoming voluntary measures, and technical and market trends in the ICT sector:

- the relevant existing policy framework (e.g. EuP Directive) and likely implementing measures (minimum efficiency performance standards) emerging from the EuP

³⁵ EuP preparatory studies lot 3, 4, 5 and 7

directive (these implementing measures are likely to require products to meet Energy star / EU Code of Conduct and EU energy labelling requirements)

- the relevant voluntary agreements (EU Code of Conduct, Industry self-commitments, etc.), voluntary labelling (Energy star, EU eco label), but also the existing mandatory labelling (EU Energy label)
- the existing/future trends in technology (existing and emerging future technologies)
- the existing/future market trends

For developing the Eco-scenario, various improvement potential scenarios from the existing EuP Preparatory Studies (more ambitious than the likely implementing measures) are compiled and other relevant literature data for products not covered by the EuP studies are also integrated.

These scenarios are built for each category of ICT end-user device (section 1.3.1.), each type of ICT infrastructure (section 1.3.2.) and are summarised in section 1.3.3.

The recommendations in terms of possible actions needed to reach the Eco-scenario are presented in the summary as most of them cover the whole ICT sector and are valid across categories of ICT equipment. The more product-specific or infrastructure specific recommendations are presented directly in the analysis of the related products/infrastructure.

1.3.1. ICT END-USER DEVICES

■ Data on ICT end-user-devices

In order to calculate the total energy impact of ICT end-user-devices, data on annual electricity consumption has been drawn from two major sources:

- EuP Preparatory Studies on: Computers (Lot 3), Imaging Equipment (Lot 4), Televisions (Lot 5), Standby and off-mode losses (Lot 6), Battery Charger and External Power Supply (Lot 7), Simple Set-Top-Boxes (Lot x), and Complex Set-Top-Boxes (Lot 18) (2007)
- Fraunhofer ISI/CEPE Study on: Energy Consumption of ICT in Germany until 2010 (2003/5)

The **EuP Preparatory Studies** are major efforts of the European Commission to assess the current environmental impact of specific product groups and their improvement potential. EuP is the synonym for the Framework Directive 2005/32/EC on eco-design requirements for Energy-using Products. In the EuP Preparatory Studies the environmental lifecycle impact of certain product groups have been assessed according to the MEEuP EcoReport methodology. This eco-assessment consists of eight impact categories including “Total Energy” (in PJ) and

“Global Warming Potential” (in CO₂ eq.). The eco-assessment covers the whole product life cycle including the manufacturing, distribution, use, and end-of-life phase. Some of the EuP Preparatory Studies also include data on the annual electricity consumption for the respective product stock in EU 25 for the year 2005. The annual electricity consumption of the individual equipment categories reflects the actual energy consumption in the use phase, which is the primary indicator for our study’s Task 1.1. The total energy footprint (whole life cycle) becomes interesting when analysing the environmental effects of the other life cycle phases (i.e. mainly production and end-of life).

The **ISI/CEPE Study**: The Fraunhofer ISI (Fraunhofer Institute for System technology and Innovation Research) together with CEPE (Centre for Energy Policy and Economics) provided in 2003 a very comprehensive study on “Energy Consumption of ICT in Germany until 2010”. This study set a first milestone in the assessment of the environmental impact of ICT. The data provided in the study have been thoroughly researched. And although the data (estimates for 2005 and 2010) are already somewhat outdated, they are still the best available source on annual electricity consumption for certain product groups such as consumer electronics, telephones and modems. For the purpose of this study the ISI data for Germany were extrapolated based on the following assumptions. In a first step the German data was allocated to the population of the EU 5 countries UK, France, Germany, Italy and Spain. Then it was assumed that EU 5 represents approximately 70% of EU-25 total. Through that assumption respective data for the European Union product stock was obtained.

1.3.1.1 Computers: Desktop Computers, Laptops, and CRT/LCD Monitors

■ Current status

The EuP lot 3 study³⁶ on personal computers provides EU-25 data on the current and future electricity consumption, and stock data of desktop and laptop computers, as well as CRT and LCD monitors. The EuP Lot 3 study provides the best available data for computers and monitors as it involved a large number of major stakeholders of this market segment. This study has also been validated by the DG TREN. However, the EuP study did not always provide the data in the desired format and some assumptions which will be explained in the course of the analysis were made to calculate e.g. the projections of electricity consumption per unit.

The 2005 annual electricity consumption for this product group amounts to approximately **42 TWh**, of which about 18 TWh is related to office equipment and about 24 TWh to household devices (30% office, 70% home).

³⁶ Source: EuP Lot 3 study (<http://www.ecocomputer.org>)

Table 8 : EU 25 estimates for computers and monitors

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/year)	Estimated Electricity Use (TWh/year)
Desktop (30% office, 70% home)	146	157	23
Laptop (60% office, 40% home)	61	83	5
CRT monitors	81	127	10
LCD monitors	68	59	4
Total Computers and monitors	356	427	42

■ BAU-Scenario

The BAU-scenario assumes that more and more computers and monitors comply with the **Energy Star 4.0 Tier I** requirements (power management enabled, energy efficiency requirements on idle modes and sleep modes (Tier II for monitors), and more efficient power supply units for computers) (Table 9, Figure 9 and Figure 10).

Table 9: EU 25 Business-as-Usual Scenario until 2020 for computers and monitors³⁷

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ³⁸ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Desktop	146	157	23	180	158	28	215	123	26
Laptop	61	83	5	154	88	14	253	75	19
CRT monitors	81	128	10	7	127	1	0	0	0
LCD monitors	68	59	4	214	59	13	276	49	14
Total Computers and monitors	n/a	n/a	42	n/a	n/a	55	n/a	n/a	59

Electr. = Electricity

³⁷ Source : EuP Lot 3 study – The study provides stock data and energy consumption data for the whole life cycle of the products in Joules. Assumptions were made that the use phase represents between 70-80% of the primary energy use during the whole life cycle in order to calculate the electricity use during use phase. A conversion factor of 10.5 was used to convert PJ (peta joules) in TWh (Factor used in the EuP EcoReport tool)

³⁸ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

Figure 9: Estimated evolution of the electricity consumption per unit of computers and monitors in a BAU-scenario

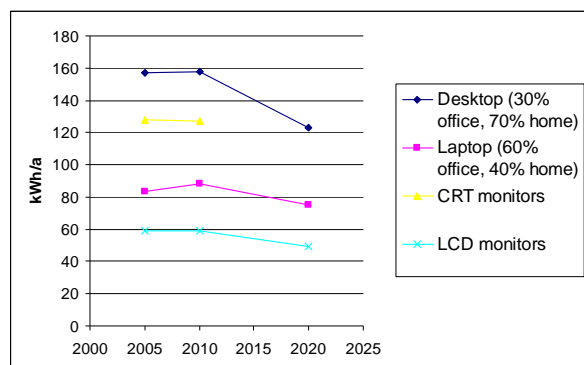
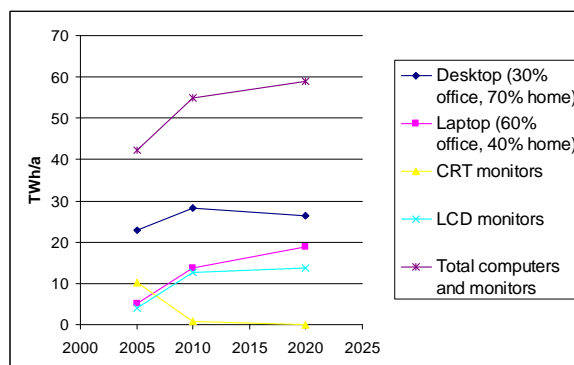


Figure 10: Estimated evolution of the electricity consumption of the stock of computers and monitors in a BAU- scenario



The data presented in Table 9 was calculated based on the stock data provided in the EuP lot 3 study and on the data related to the primary energy use during the whole life cycle of computers and monitors, assuming between 70 % and 80 % is used during the use phase. It should be noted that Table 9 provides estimates of the electricity consumption per unit referring to a product in stock on the EU 25 market for a given year and does not provide data for the new products introduced in the market for a given year.

This scenario (from EuP Lot 3) and based on the following trends:

- Computers: desktops and laptops (30% office use, 70% home use)

Trends increasing the total electricity consumption:

- Increased penetration rate of computers (mass adoption of electronic devices at home and at work)
- Increase in storage capacity and development of faster devices. This is also driven by the needs of new operating systems: they require better hardware, faster processors, more RAM, better graphic cards, and more hard disk space.

Trends reducing the total electricity consumption:

The producers have already introduced many improvements in the products and others are in the pipeline, which lead to reduced energy consumption. The improvements range from hardware changes to simplifications in the systems to promote users to accept and adopt the different power management options already available today. Other market driven trends also play an important role in the overall electricity consumption of computers. The electricity consumption of computers is estimated to be slightly increasing until 2010 because of the reasons described above. However, this trend will be reversed by 2020 (see Figure 9) with the uptake of more efficient computers and a higher proportion of laptops:

- Market **shift from desktops to laptops** (a laptop consumes approximately 40 % less electricity compared to a desktop computer)
- More and more computers are fitted with **multi core processors** (introduced in 2006). Estimates show that a dual core processor can enable over 60 % energy savings of the processor compared to a single core processor. This translates into 24 % energy savings on desktops and 12 % in the case of laptops³⁹.
- Since 2005, more and more computers are being shipped with the **power save functionality enabled** (advanced power management in modern computers could enable up to 60 % electricity savings).
- Use of **adaptive clock frequency** for desktops which can reduce the computer's electricity consumption by as much as 16 % (see for example the Intel Speedstep technology) – the challenge today relies less on improving individual components but more on the improvement of the entire system, e.g. introduction of microprocessors with “multiple speed steps” or multiple levels of power consumption that the microprocessor can step up or down when higher or less demanding applications are run on the computer.
- Introduction of **more energy efficient power supplies**. It can be mentioned that due to thermal constraints of desktop PC systems, it is likely that power supply efficiencies will improve in the coming years.
- In the future, the use of alternatives to a conventional hard drive in the form of **Flash drives** (as currently in USB memory sticks, or MP3 players) could reduce the computer's electricity consumption of about 7 watts (not a mature technology yet). Hybrid hard disks (combination of hard disk and flash drive) could also be a future technology reducing the electricity consumption of computers.
- Use of **LED black light monitors** in laptops could reduce power consumption of laptops of over 7 %.

In long-term, the technologies also foresee the introduction of **thin clients** instead of desktops (a thin client is a PC without a hard drive containing an operating system in RAM but relying on a server for other software applications) for use in normal office applications. The energy consumption of the thin client is low, but the major drawback is that it cannot be used as a standalone PC. However, due to the low energy consumption, there has been an increased interest in this type of PCs for office use in the last years.

- CRT and LCD monitors

Trends increasing the total electricity consumption:

³⁹ According to EuP Lot 3 study, the processor represents about 40 % of the energy use of a desktop and 20 % of the energy use of a laptop (use phase)

- Increased penetration rate of monitors (mass adoption of electronic devices at home and at work)
- Potential **increase in the size of monitors' screens**

Trends reducing the total electricity consumption:

- Market **shift from CRT to LCD monitors**, with CRT monitors disappearing from the EU market end of 2012 (replaced by LCD monitors which typically consume approximately 45 % of the electricity required for CRT monitors).
- Switch from fluorescent lamps to **LED backlights in LCD monitors**: adoption of a backlight unit, (BLU) could reduce the energy consumption by 25 % when the technology matures.
- Introduction of **OLED Displays** instead of LCD displays (organic light-emitting diode). At present OLEDs are used in small and relatively short-lived portable colour video displays (e.g. mobile phones, digital camera). Large-screen colour displays have been demonstrated, but their life expectancy is still too short. The industry estimate indicates that full size computer displays with the OLED technology is still 4-5 years away.

■ Eco-Scenario

The Eco-scenario projects a situation where stricter requirements are formulated for computers and monitors. The EuP Lot 3 study proposes 4 alternative scenarios to the BAU.

Among these 4 scenarios, the scenario leading to the lowest energy consumption per unit was chosen as the Eco-scenario. This Eco-scenario assumes minimum energy requirements are put in place in 2009 and 2011, through implementing measures set by the EuP Directive.

It is interesting to note that the EuP Lot 3 study also proposed a "Industry recommendation" based scenario built on eco-design requirement options formulated jointly by EICTA, AeA (USA high tech business association), and JBCE (Japan Business Council Europe) which mainly included enabled power management and power supply efficiency requirements and lead to a slightly higher projected impacts of computers and monitors in terms of electricity consumption compared to the Eco-scenario presented here (see the example of desktops in Figure 11).

Figure 11: Illustration of the various scenarios developed under EuP lot 3

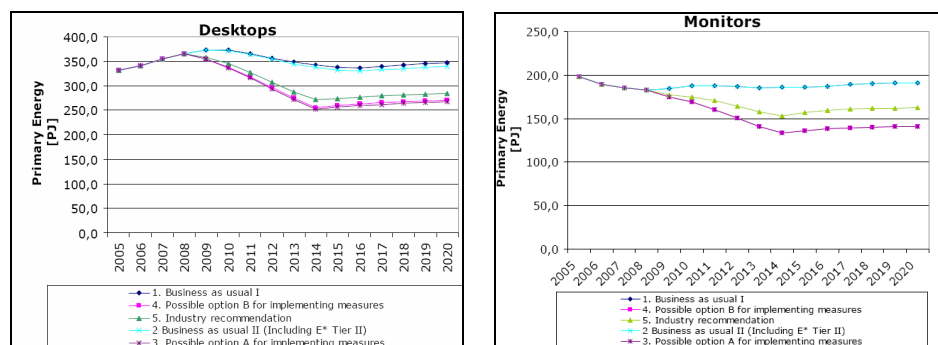


Table 10: EU 25 Eco-Scenario until 2020 for computers and monitors⁴⁰

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Desktop	146	157	23	180	142	26	215	95	20
Laptop	61	83	5	154	80	12	253	63	16
CRT monitors	81	128	10	7	118	1	0		0
LCD monitors	68	59	4	214	53	11	276	36	10
Total Computers and monitors	n/a	n/a	42	n/a	n/a	50	n/a	n/a	46

Electr. = Electricity

Figure 12: Estimated evolution of the electricity consumption per unit of computers and monitors in an Eco-scenario

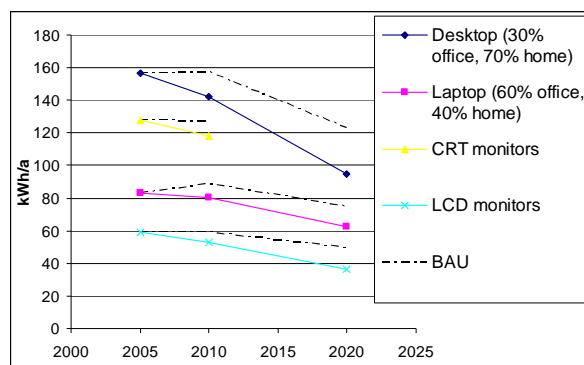
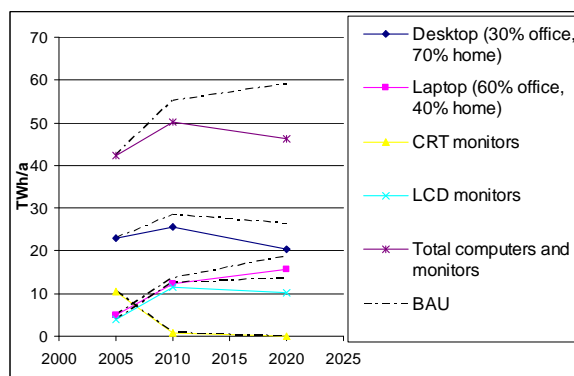


Figure 13: Estimated Evolution of the electricity consumption of the stock of computers and monitors in an Eco-scenario



The main assumptions for developing the Eco-scenario are the following:

Trends increasing the total electricity consumption:

- Same as in the BAU scenario

Trends reducing the total electricity consumption:

- **Energy Star requirements** are implemented as assumed in Business-as-usual
- **Power management** is assumed to become mandatory at the time of delivery to the customers by 2009

⁴⁰ See footnote ³⁷

- **High efficiency external power supply** units for desktops, laptops and monitors become mandatory by 2009. With modern technology of switched power supplies, the efficiency of power supplies for computers can be as high as 90% (Energy star states 80 %). There is an initiative from the industry to build more efficient internal power supplies called “80-plus”. These requirements state that the power supplies shall have an energy efficiency of greater than 80 % at 20 %, 50 %, and 100 % of rated load with a true power factor of 0.9 or greater (80-plus⁴¹).
- **Minimum requirements** for standby and off modes become mandatory by 2009 (harmonised with Energy star Tier I requirements)
- Minimum requirements for idle mode for computers become mandatory 2010 in line with Energy Star criteria, Tier I. It is assumed that all new products will comply with these requirements from 2010, leading to the full stock compliance in 2016
- Minimum requirements for power per resolution for monitors are estimated to become mandatory in 2009 (harmonised with Energy Star Tier I requirements and then further developed in 2011)
- The requirement for active/on-mode power per area for monitors is estimated to become mandatory in 2011 and complemented with the newly developed Energy Star criteria for monitor active on-mode power. It is estimated to decrease the average power for monitors in active mode by 5 %

Overall, these driving factors in an Eco-scenario would reduce the electricity consumption of desktop PCs by 22 % in 2010 (40 % in 2020), of laptops by 10 % in 2010 (25 % in 2020) and of LCD monitors by 16 % in 2010 (38 % in 2020), compared to the reference 2005 situation. These estimated improvement potentials of the average European products are below the **targets announced by the industry**, because these targets are about new products placed on the market in 2010 and not about average EU 27 products installed on the market in 2010:

- The “**Climate Savers Computing initiative**”⁴², started by Google and Intel brings industries and other stakeholders together and encourages energy efficiency improvement for computers and servers. This initiative, similar to the Energy Star program, intends to promote both the deployment of existing technologies and investment in new energy-efficiency technologies. In addition, it puts limits on the energy used by devices when inactive and requires systems to be shipped with power management features enabled. The Initiative starts from the 2007 Energy Star requirements for desktops, laptops, and workstations (including monitors), and

⁴¹ 80-plus at <http://www.80plus.org>

⁴² <http://www.climatesaverscomputing.org/>

gradually increases the efficiency requirements over the next 4 years. **The initiative targets a 50% reduction in annual energy consumption of computers by 2010.**

Other industry efforts can be mentioned such as the Intel power saving advisory website (linux users⁴³).

- Summary and conclusions
- Identification of the barriers for energy efficiency and recommendations

Table 11 shows that for the year 2020, potentially 13 TWh could be saved if the future computers and monitors followed the ECO-scenario development, compared to a BAU situation. Highest potential savings rely in desktop computers (6 TWh) and LCD monitors (4 TWh), followed by laptops (3 TWh).

Barriers for achieving such Eco-scenario were identified in the EuP lot 3 study as being not so much related to technical barriers. Leading companies of the ICT sector have already shown that energy efficient ICT products can be manufactured (e.g. energy efficient processors); however, this trend is not followed by the majority as shown by the difference between the average European electricity consumption per unit for computers and monitors (EuP lot 3) in 2020 in an ECO scenario, which is above the electricity consumption observed in 2007 best available products on the market. Indeed, insights of the best performing products on the EU market available in 2007 show that technically, high efficiency products are feasible (Figure 14), however at high cost

Table 11: Estimated improvement potential BAU/ECO-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Desktop	23	26	20	6
Laptop	5	19	16	3
CRT monitors	10	0	0	0
LCD monitors	4	14	10	4
Total computers and monitors	42	59	46	13

⁴³ « *www.LessWatts.org is not about marketing, trying to sell you something or comparing one vendor to another. LessWatts.org is about how you can save real watts when you use Linux* on your computer or computers* »

Figure 14: BAU and Eco-scenarios for computers and monitors (total electricity use during use phase)

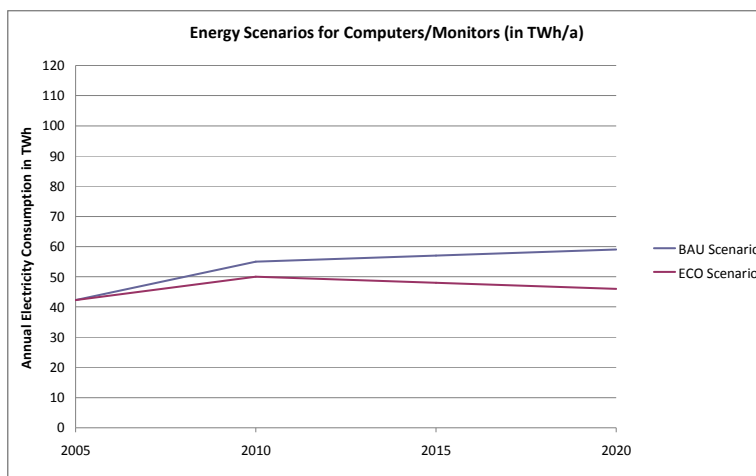


Table 12: Comparison of projected average electricity consumption of products in stock in EU 25 with actual electricity consumption per unit of best available products on the EU 25 market

Annual electricity consumption per unit kWh/a	Desktop	Laptop	CRT	LCD
BAT available products 2007 (new products)	53	18	114	33
BAU 2005 (average installed products)	157	82	127	59
BAU 2020 (average installed products)	123	75	N/A	49
ECO 2020 (average installed products)	95	63	N/A	36

In the EuP Lot 3 study on personal computers and monitors the main barriers for the introduction of new technologies and products on the market were identified. For most manufacturers the barriers are cost-related but also there is a fear of introducing the new solutions at the “wrong time”. The hardware must be able to harbour several different generations of software but also old ones, thus there are certain limits for disruptive developments. Some manufacturers also expressed **the lack of clear and consistent signals and awards from customers** including the public sector that would meaningfully award manufacturers of energy efficient ICT products. At the consumer level, the main inhibiting factor is the focus on cost and performance of the product rather than on its energy efficiency. Also, at the level of manufacturers, the lack of standards is identified as the most significant barrier for the introduction of new technologies. The creation of next standards at the EU level based on the CEN, CENELEC, ETSI organisations, which covers activities within the ICT sector or at the International level through the IEC (International Electrotechnical committee) ISO, or ECMA should therefore be encouraged. The legal basis for European standardisation (including the ICT domain) is Directive 98/34/EC. It formally recognises the three European Standards Organisations, CEN, CENELEC and ETSI, active in the ICT sector. The yearly ICT standardisation programmes aim at promoting standardisation work in support of EU policies and legislation. A study on the specific policy needs for ICT standardisation is already ongoing. Its objective is to analyse the present state of the

European standardisation policy and to bring forward recommendations for its future development.

In order to overcome these barriers, **voluntary actions** such as Energy Star, EU Energy labelling but also legislation (EuP Directive future implementing measures) and industry initiatives are under development. Voluntary measures are believed to be more beneficial than mandatory requirements in a fast moving sector such as ICT, as they are more flexible and rapid to be put in place.

Also, it could be recommended to set **mandatory green public procurement (GPP)** for office ICT equipment for computers and monitors in order to encourage the take up of efficient products.

Both the extension of the scope of the EU Energy label and the decision of making GPP mandatory for office ICT equipment would have the effect to leverage the demand for energy-efficient products from respectively private and public consumers.

- R&D and innovation

Moreover, **research activities** under the 7th Framework Programme already exist and should continue to be encouraged in order to boost the development of the identified future energy efficient technologies and speed up the penetration of more efficient ICTs on the EU market. More specifically for computers and monitors:

- ENIAC and ARTEMIS

To speed up the development of e.g. **flash memory, efficient power supplies, computing systems**, the European Commission has launched (end of February 2008) two new Joint Technology Initiatives (JTIs) designed to boost Europe's competitiveness in the fields of nanoelectronics and embedded computer systems. The budgets of the JTIs (€3 billion over 10 years for ENIAC and €2.5 billion for ARTEMIS) will come from the participating industry and research organisations, the European Commission and other public authorities.

- Photonics 21

To support the development of e.g. **LCD displays and OLED displays**, the Technology Platform Photonics 21 was established to enable and support a continuous knowledge transfer between members of this business sector.

- Industry and innovation

Also, the **industry itself is developing innovative products and components**, and huge improvements have been made, specifically through improved chip design with leading manufacturers competing to stay at the forefront of efficiency. Some innovations are highlighted by a UK study recently published:

For example, Eneco developed a new chip technology (semiconductor) based on principles of thermionic energy conversion, that will convert heat directly into

electricity, or alternatively refrigerate down to -200 °C when electricity is applied. The result is a “thermal chip” which can operate at temperatures of up to 600°C and deliver absolute efficiencies (in terms of how much heat energy is converted to electricity) of between 20 and 30%. There is scope for chips replacing high end lithium ion and polymer batteries, but the major scope is in **integrating the heat conversion chips into computing devices to take advantage of the heat generated by processors and turn it into electricity to power fans or other cooling technologies.**

Again, this stresses that measures should be taken to encourage the uptake of such efficient components and products as the technology is already available.

1.3.1.2 Television (TV)

■ Current status

The stock calculations in the EuP Lot 5 study⁴⁴ include CRT (cathode ray tube), LCD (liquid crystal diode), PDP (plasma display panel), RP (rear projection) TVs, and TV component units. This does not include single monitors (already analysed above), video beamers⁴⁵, and portable devices (see section 1.3.1.4).

- Status: The annual electricity consumption of TVs (EU 25 in year 2005) was estimated to be 54 TWh/a according to the Lot 5 Study. With 1.5 devices in each household, TVs are major contributors of home energy consumption. The total energy consumption has been increasing constantly over the past years due an ongoing shift in technology. The energy consumption of TVs is currently influenced by the following technical trends:
 - Form - from small cubic (CRT) to large screen flat panel (LCD, PDP)
 - Resolution – from standard (PAL/SECAM) to high definition (HDR/FHD)
 - Broadcasting standard - from analogue to digital (DVB-T/-S/-C).
 - More integrated functionality (digital tuner, hard disk drives, memory)
 - TV centred, always online home entertainment (network standby)
- Mid-term trends: The total energy consumption will almost **double by 2010** due to the increasing amount of medium and large screen sizes with high on-mode power consumption. The shift to “modern” flat panel TVs will increase the number of **secondary sets per household**. The on-going technical shift will continue until 2020 with complete change to digital broadcasting (DVB), full high definition (FHD), and advanced display technology including LCD with LED backlights and Organic LED displays. Due to the novelty of some display technologies, it might take a longer

⁴⁴ EuP Lot 5 on Televisions : <http://www.ecotelevision.org>

⁴⁵ Video beamers have not been assessed so far. But are estimated not to be important and therefore negligible in term of electricity consumption

time until an improvement is visible in the market. The relatively long lifetime of a TV (8 to 16 years) is the reason for its extended secondary use. Through that, less efficient TVs will remain in the market for a considerable period of time.

Table 13: EU 25 estimates for TV in 2005

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Total TVs	275.9	195.7	54

■ BAU-Scenario

The business-as-usual scenario for TVs follows the technical trends, stock and use scenario outlined in the Task 8 report of the Lot 5 Studies. The basic assumptions for BAU scenario are:

- Further stock increase until 2020 due to a shift in technology
- TV stock is dominated by medium and large screen sizes in 2020 (>32")
- 4h on-mode and 20h network-standby for primary and secondary products
- EuP implementing measures regarding minimum power consumption requirements (on-mode and standby) are expected to take effect after the year 2010 and will be implemented in the stock by 2020.

According to the BAU scenario, the annual electricity consumption will almost double by 2020 by and reach 116 TWh/year. The increase will be most rapid until 2010 due to the technical shift in the market. Beyond 2010, the increase is likely to slow down due to the introduction of more mature, energy efficient display technologies as well as the minimum requirements expected to be implemented in the framework of the EuP Directive.

Table 14: TV BAU scenario for EU 25 (2005 – 2020)

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁴⁶ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total TV	275.9	195.7	54.0	391.5	232.1	90.8	410.8	283.4	116.4

Electr. = Electricity

■ Eco-Scenario

⁴⁶ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

The Eco-scenario for TVs follows the technical trends, stock and use scenario outlined in the third “best practice” scenario of the Lot 5 Study. This scenario assumes that an energy label is set up for TVs and that all TVs achieve **40% improvement compared to a BAU 2020 situation** which means the power consumption values of the **“B class” energy efficiency label**. The impacts for the reference years 2005 and 2010 are identical to the previous “business as usual” scenario because the EuP measure will take effect following the year 2010. We have to assume that smaller and medium screen sizes can achieve a B class value more easily than the large screen sizes which will need a longer time period to reach such values.

According to this eco-scenario, the annual electricity consumption will still increase until 2020 by a 1.3 factor and reach 70 TWh/a. The increase is more moderate but still driven by the market shift towards larger and high definition TVs. The assumed improvement of 40% is a challenge particularly for the large PDPs. On the other hand, new LED-based display technologies show a considerably higher improvement potential. However, such advanced technologies will not reach maturity until 2015.

Table 15: TV Eco-scenario for EU 25 (2005 – 2020)

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total TV	275.9	195.7	54.0	391.5	195.7	76.6	410.8	170.9	70.2

Electr. = Electricity

- Summarising table and conclusions

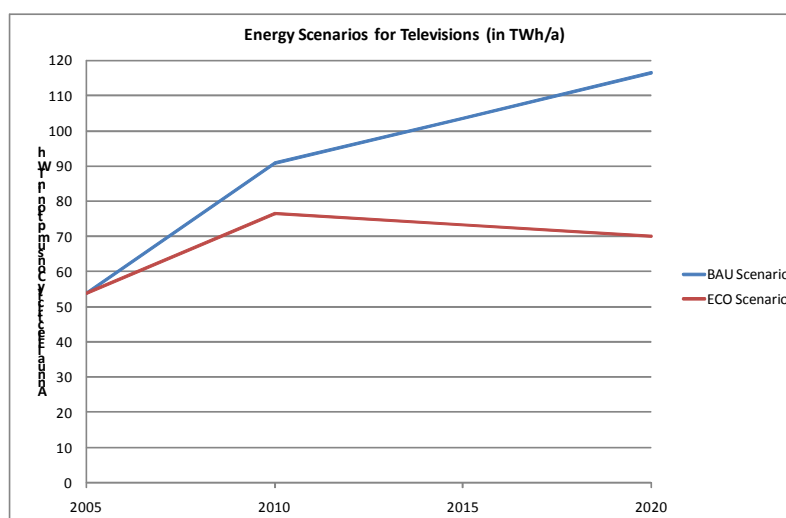
The TV sector will have a considerable impact on household electricity consumption over the next two decades. The overall electricity consumption is increasing even under the assumptions of an Eco-scenario. User behaviour (watching time, putting in standby, etc.) can of course influence the overall energy consumption but the major part of the improvement potential is technology driven. Energy efficiency has to be addressed as a key functional parameter in the development of **new display technologies**. The European industry has in that respect a limited influence as most advanced technologies in the area of TVs originate in Japan and South Korea.

Business initiative in the TV sector exist, encouraged by for example the Eco-labelling: Sharp is currently leading the field in environmentally friendly televisions with its recently announced 'GA9E Series' LCD TV range which has been awarded the EU Ecolabel for their low energy consumption and contribution to reducing carbon dioxide emissions (CO₂).

Table 16: TV estimated improvement potential BAU/ECO-scenario for TVs (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total TV	54.0	116.4	70.2	46.2

Figure 15: BAU and Eco-scenarios for TVs (Total electricity use during use phase)



1.3.1.3 Imaging Equipment⁴⁷

■ Current Status

The stock calculation includes Inkjet (IJ) and Electro Photography (EP) based copiers, printers and multifunctional devices (MFDs) in monochrome and colour. Flatbed scanners and facsimiles are not included in the assessment. However, flatbed scanners were assumed to represent a negligible share of the energy consumption of the ICT sector and facsimiles machines are covered in section 1.3.1.9.

- Status: For the analysed product scope the Lot 4 study came to the conclusion that office imaging equipment has a high potential for energy efficiency **under the condition of conscious product use**. Total annual electricity consumption in 2005 was 7.8 TWh. depending on the use pattern – particular EP products with high ready mode power consumption – the actual electricity consumption could be 50% higher resulting in approximately 12 TWh/a. The good level of energy efficiency achievable through technical means (i.e. not dependant on user behaviour) seems to be related to the wide acceptance of the Energy Star in the field of imaging equipment.

⁴⁷ Source: EuP Lot 4 study (<http://www.ecoimaging.org>)

- Mid-term trends: The market is not yet saturated and the stock will moderately increase by about 15 % until 2020. Disrupting new marking technologies or products have not been identified by the Lot 4 Study. The main trends in product design are:

- Market shift from EP-Copier/SFD to EP-Copier/MFD almost complete
- Market shift from EP-Printer/SFD to EP-Printer/MFD and in conjunction with the ongoing shift to colour
- Mono EP-Printer (high speed volume printer) still considerable market
- Market shift from IJ-SFD to IJ-MFD ongoing with 75% MFD in 2010
- MFDs and Colour become mainstream due to performance and price

These technical trends have only a minor influence on overall electricity consumption and a greater influence can be made by a change in the use patterns and through the utilisation of the power management options by the consumer.

Table 17: EU 25 estimates for Imaging Equipment

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Total Imaging Equipment	113.2	54.8	7.8

■ BAU-Scenario

The business-as-usual scenario is an extrapolation of the Lot 4 six base case's annual electricity consumption until 2020 according to the product stock development.

For this specific product group, the possible EuP implementing measures are very uncertain. And therefore the BAU scenario considers no implementing measures (the implementing measures will constitute the Eco-scenario in this specific case).

Regarding the EP-product case, it is assumed that in the mid-term the average energy efficiency improves from factor 0.8 Energy Star TEC Tier 1 to factor 0.7 Energy Star TEC Tier 1⁴⁸. In the BAU-scenario, the overall energy consumption increases until 2020 only by factor 1.2 or 9.4 TWh/a. This is mainly related to the increase in stock. A worst case scenario published in the Task 8 report of Lot 4 Study shows a maximum increase to 14.1 TWh/a. This is factor 2 in comparison to the base case assumption in the reference year 2005.

⁴⁸ Energy Star Tier 1 is Factor 1. A factor 0.8 means that the product is better than the Energy star requirement by 20%

Table 18: EU 25 BAU-scenario until 2020 for Imaging Equipment

	2005 (EU 25 estimates)			2010 (EU-25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁴⁹ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Imaging Equipment	113.2	68.9	7.8	132.4	62.7	8.3	146.0	64.4	9.4

Electr. = Electricity

■ Eco-Scenario

The Eco-scenario has the intention to show the improvement potential that is indicated already today by many products that are registered under the Energy Star or other Labeling schemes. It seems a quite realistic scenario reflecting also the proposed EuP requirements and mid-term policy measures that have been recommended. The proposed measures should result in a constant improvement as it is already noticeable over the past years. A continuous improvement of energy efficiency with respective market proliferation is assumed. According to this assumption the average energy consumption of EP-products by the year 2005 has already reached a factor 0.7 Energy Star TEC Tier 1. By the year 2020 the average market has reached a factor 0.5. This scenario reflects **technical solutions for fast reactivation and effective power management** which will reduce overall energy consumption in the transition phase to network standby. The scenario also reflects a **conscious improvement of network standby power consumption and off-mode**. It reflects an expected energy improvement concerning colour capable EP-products through more mature technologies. Finally Lot 4 has made some **more ambitious assumptions on network standby for IJ-products reflecting best available technology**.

As a result of these assumptions the annual electricity consumption is declining by factor 1.2 to 6.2 TWh/a in the year 2020. This is a very positive development; moreover, further improvement seems possible, however, strongly influenced by user behaviour.

⁴⁹ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

Table 19: EU 25 Eco-Scenario until 2020 for Imaging Equipment

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Imaging Equipment	113.2	68.9	7.8	132.4	53.6	7.1	146.0	42.5	6.2

Electr. = Electricity

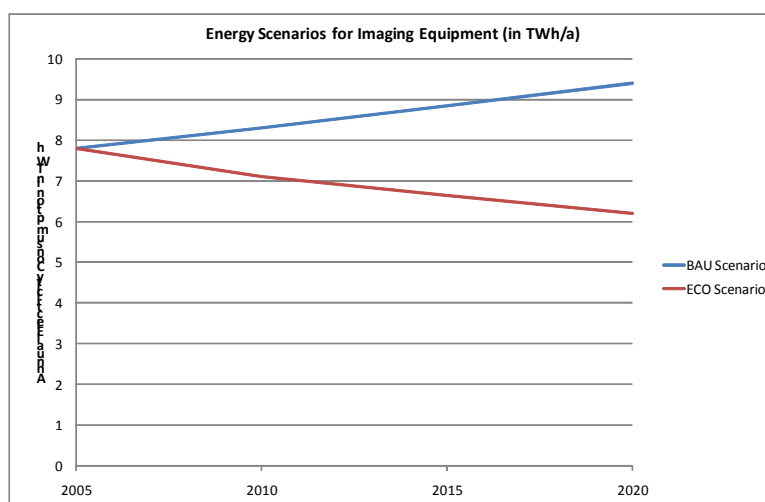
■ Summary and conclusions

Imaging equipment have a good improvement potential and it is likely that the overall electricity consumption remains on the level of 2005 or even drops in the long-term. Imaging equipment however provides a good indication (also valid for other ICT products) on the growing impact of network standby. It is an example for the necessity of new test procedures (standards to measure energy consumption under certain network conditions).

Table 20: Estimated improvement potential BAU/Eco-scenario for imaging equipment (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total Imaging Equipment	7.8	9.4	6.2	3.2

Figure 16: BAU and Eco-scenarios for imaging equipment (electricity use during use phase)



1.3.1.4 Mobile Devices (digital cameras, camcorder, etc.)⁵⁰

■ Current Status

Mobility devices include products such as digital cameras and camcorders which can be regarded as computer peripherals. Energy consumption of mobile devices has to be seen in conjunction with the charging power consumption and the respective cycles or use patterns. Off-mode losses are critical.

- **Status:** The electricity consumption for mobile devices is calculated with the use pattern from the EuP Lot 7 study. The assumptions are that the devices are 10 h/d in no-load with energy losses of 0.3 W and 1 h/d the charger loads the devices with 6.5 W rated output and an efficiency of 70%. For this product segment the 2005 annual electricity consumption is approximately 0.5 TWh caused by 108.0 million units.
- **Trends:** The growing proliferation of digital cameras will increase the stock of mobile devices in the coming years. Trade-offs through the replacement of single function devices could occur.

Table 21: EU 25 estimates for Mobile Devices (2005)

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Total Mobile Devices	108.0	4.5	0.5

■ BAU-Scenario

For the business-as-usual scenario, the stock growth assumes an annual growth of 9.4% from 2005 to 2010 and 5% from 2010 to 2020. The energy consumption per device stays constant at 4.5 kWh/year until 2020.

Table 22: EU 25 BAU-scenario until 2020 for Mobile Devices

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁵¹ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Mobile Devices	108.0	4.5	0.5	169.2	4.5	0.8	275.7	4.5	1.2

Electr. = Electricity

⁵⁰ Source: EuP Lot 7 study (<http://www.ecocharger.org>)

⁵¹ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

■ Eco-Scenario

The Eco-Scenario is based on the same stock development as the BAU-Scenario, but it is assumed that the **chargers of the mobile devices are not left in no-load**. Therefore, the electricity use per unit drops to 3.4 kWh/a. It is unlikely that really all chargers are unplugged every time the device is not loaded. But this Eco-Scenario shows the potential of user behaviour change. That the devices themselves become much more efficient cannot be assumed as mobile devices all already developed to provide a maximum of autonomy (service hours) and therefore already very energy efficient. According to the EuP Lot 7 study, there is not much improvement potential for the chargers as they are, in this voltage range, already very efficient.

Table 23: EU 25 Eco-scenario until 2020 for Mobile Devices

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Mobile Devices	108.0	4.5	0.5	169.2	3.4	0.6	275.7	3.4	0.9

Electr. = Electricity

■ Summary and conclusions

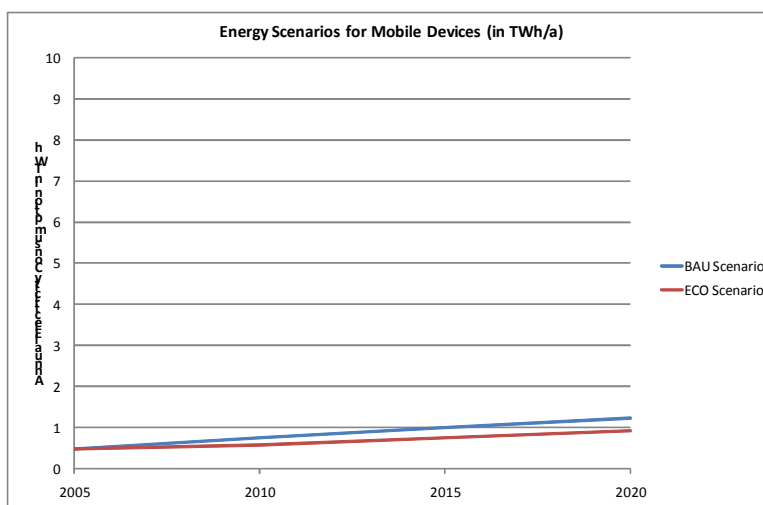
The improvement potential for 2020 (difference between BAU- and ECO-Scenario) is 0.3 TWh. In this case, the improvement potential is not reached through technical **improvements of the devices/charger but through assumed change in user behaviour**.

Recommendations will be further provided in the summary section 1.3.3.3.

Table 24: Estimated improvement potential BAU/Eco-scenario for mobile devices (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total Mobile Devices	0.5	1.2	0.9	0.3

Figure 17: BAU and Eco-scenario for mobile devices (electricity use during use phase)



1.3.1.5 Audio Systems

■ Current Status

The stock including compact systems, stereo system and clock radios has been extrapolated from the ISI study in order to lead to 2005 data.

- Status: Original figures for Germany were 85.9 millions. These figures were extrapolated from the ISI/CEPE Study. For the EU-25 we estimate a stock of 455.7 millions units for the year 2005.
- Trends: For Germany, the number of devices will rise slightly until 2010, but at the same time the total energy consumption will slightly decrease, which is caused by reduced energy consumption in standby. Networked (active) standby, for digital radio broadcasting, is becoming a major issue and needs further attention.

The energy consumption was calculated with assumptions similar to ISI study. The use pattern is assumed to be similar to the TVs, 4 h/d on and 20 h/d in standby for all audio devices. The electricity consumption in standby and on-mode were used as follows:

- compact system:
 - standby: 5 W
 - on-mode: 30 W
- stereo systems:
 - standby: 5 W
 - on-mode: 40 W

- clock radios:
 - standby: 2 W
 - on-mode: 5 W

These values have to be seen as averages of devices as especially individual stereo systems can have an electricity consumption of 200 W and more.

Table 25: EU-25 estimates for Audio Systems

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Compact system	108.5	80.2	8.7
Stereo system	158.0	94.9	15.0
Clock radio	189.2	21.9	4.1
Total Audio Systems	455.7	n/a	27.8

■ BAU-Scenario

The stock for the business as usual scenario is based on the extrapolated figures from the ISI study. The stock increases slightly together, but within the total stock for audio devices there is a shift towards stereo system. As the ISI study does not have any figures for 2020, one device per inhabitant (496.4 million inhabitants in EU-27 in 2020) is estimated with the same share of the devices as stated by ISI for 2015. For the electricity consumption the following figures were estimated:

- compact system:
 - standby 2010: 5 W; 2020: 1 W
 - on-mode 2010: 20 W; 2020: 15 W
- stereo systems:
 - standby 2010: 5 W; 2020: 1 W
 - on-mode 2010: 40 W; 2020: 40 W
- clock radios:
 - standby 2010: 2 W; 2020: 1 W
 - on-mode 2010: 5 W; 2020: 5 W

By 2020, all audio systems should reach a standby value of 1 W. This would reflect expected EuP minimum requirements. Stereo systems' on-mode power consumption is not expected to improve, because of the relatively high electricity consumption of the speakers and the amplifiers. For the compact systems, a slight improvement is expected due to miniaturisation of electronic components.

Table 26: EU 25 BAU-scenario until 2020 for Audio Systems

	2004 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁵² (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Compact system	108.5	80.2	8.7	109.9	65.5	7.2	117.0	29.1	3.4
Stereo system	158.0	94.9	15.0	167.3	94.9	15.9	183.6	65,9	12.1
Clock radio	189.2	21.9	4.1	186.9	21.9	4.1	195.8	14,8	2.9
Total Audio Systems	455.7	n/a	27.8	464.1	n/a	17.5	496.4	n/a	18.3

Electr. = Electricity

■ Eco-Scenario

The assumptions for the electricity consumption in the ECO-Scenario are given below:

● Compact system:

- standby 2010: 1 W; 2020: 0.5 W
- on-mode 2010: 15 W; 2020: 10 W

● Stereo systems:

- standby 2010: 1 W; 2020: 0.5 W
- on-mode 2010: 30 W; 2020: 30 W

● Clock radios:

- standby 2010: 1 W; 2020: 0.5 W
- on-mode 2010: 3 W; 2020: 3 W

For the Eco-Scenario lower values for on-mode and standby are used which can be achieved through the use of best available technologies (BAT).

⁵² This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

Table 27: EU-25 Eco-Scenario until 2020 for Audio Systems

	2004 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁵³ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Compact system	108.5	80.2	8.7	109.9	29.1	3.2	117.0	17.9	2.1
Stereo system	158.0	94.9	15.0	167.3	50.8	8.5	183.6	47.4	8.7
Clock radio	189.2	21.9	4.1	186.9	11.8	2.2	195.8	8.2	1.6
Total Audio Systems	455.7	n/a	27.8	464.1	n/a	13.9	496.4	n/a	12.4

Electr. = Electricity

■ Summary and conclusions

The **overall trend is positive**. Despite increase of stock, the improvement in on-mode power consumption, as well as standby and off-mode, should lead to a considerable reduction in energy consumption. Under the condition of a BAU-scenario, a decrease in annual electricity consumption by factor 1.5 can be expected, and in the case of best practice a decrease by factor 2.2.

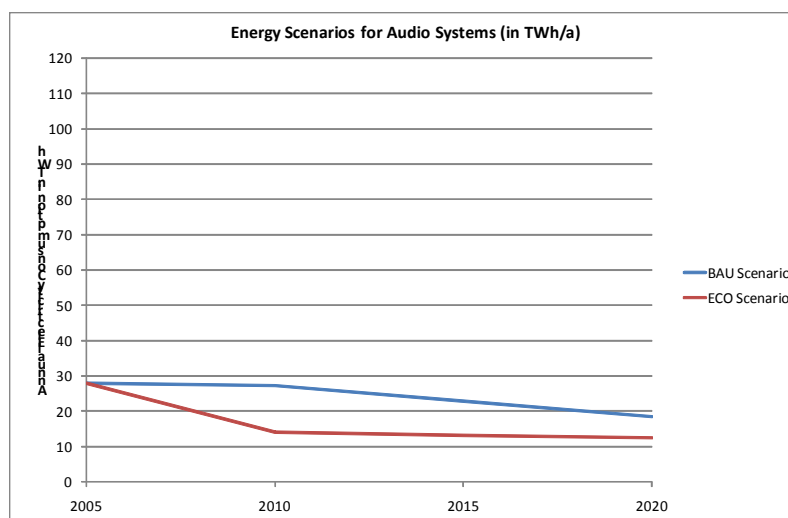
The standby mode is the main source of “leaking electricity” for these devices.

Table 28: Estimated improvement potential BAU/Eco-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2004	2020 BAU	2020 ECO	BAU-BAT
Compact System	8.7	3.4	2.1	1.3
Stereo system	15.0	12.1	8.7	3.4
Clock radio	4.1	2.9	1.6	1.3
Total Audio Systems	27.8	18.3	12.4	5.9

⁵³ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

Figure 18: BAU and Eco-scenarios for Audio systems (electricity use during use phase)



1.3.1.6 VHS/DVD equipment

■ Current Status

The original figures from ISI cover only Germany, The stock for 2005 was estimated based on data from 2001/3. The stock including VHS recorder/player and DVD recorder/player has been extrapolated from the ISI study.

- Status: Original figures for Germany were 35.3 million units. For the EU-25 we estimate a stock of 187.4 million units for the year 2005.
- Trend: According to ISI/CEPE, the total number of VHS/DVD players (with a shift towards DVD players/recorders) as well as the total energy consumption will decrease due to the utilisation of advanced electronics. According to the Lot 6 study, there will be a slight shift within the DVD segment towards recorders and complex Set-Top-Boxes with integrated DVD drives. There is also a shift to high definition DVD (Blu-Ray). These formats are supported by a higher data compression standard MPEG 4/6 with respective increased requirements on memory and data processing power. Networked standby will also contribute considerably to their total energy consumption in the future.

For the VHS /DVD equipment, the following use pattern was used for all technologies (DVD, VHS, Blu-Ray, etc.):

- 1 h/d in on-mode at 20W
- 23 h/d standby at 2W

Table 29: EU 25 estimates for VHS/DVD Equipment (2005)

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Total VHS/DVD Equipment	187.4	24.1	4.5

■ BAU-Scenario

The business as usual scenario is based on stock data extrapolations for 2010 and 2015 based on Fraunhofer ISI (2003). Due to a lack of adequate long-term stock data we assume that the stock of 2015 is comparable to the stock of 2020. The scenario follows the assumption that the energy consumption and use pattern of the year 2005 are not changing and remain the same until 2020. A real improvement in the energy efficiency is not expected due to the relative maturity of the technology. It is more likely that the energy consumption per product will increase as the players/recorders for high definition DVD tend to have higher electricity consumption due to the more complex coding/decoding data processing. The first generation of HD DVD Player demanded 40W in on-mode.

Table 30: EU 25 BAU-scenario until 2020 for VHS/DVD Equipment

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁵⁴ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total VHS/DVD Equipment	187.4	24.1	4.5	165.8	24.1	4.0	149.5	24.1	2.3

Electr. = Electricity

■ Eco-Scenario

For the Eco-Scenario the same use pattern as for the BAU-Scenario is assumed, but with lower electricity consumption per unit. For the VHS /DVD equipment the following use pattern was used in the eco-scenario for all technologies (DVD, VHS, Blu-Ray, etc.):

- 1 h/d in on-mode at 15W
- 23 h/d standby at 1W

This is a very optimistic scenario as newer products tend towards higher not lower energy consumption (as stated above).

⁵⁴ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

Table 31: EU 25 Eco-scenario until 2020 for VHS/DVD Equipment

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Audio Systems	187.4	24.1	4.2	165.8	13.9	2.3	149.5	13.9	2.1

Electr. = Electricity

■ Summary and conclusions

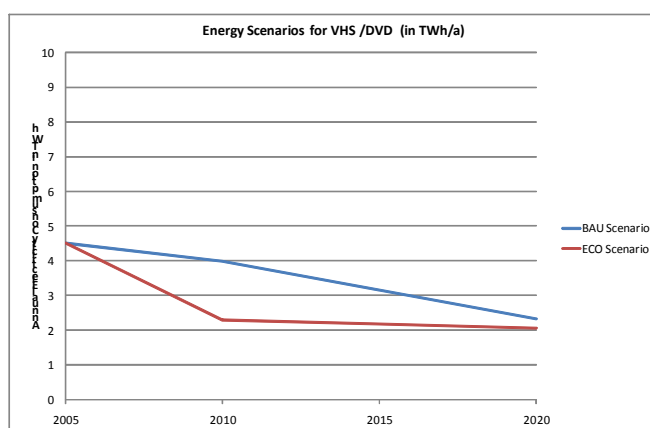
Due to the fact that on-mode power is dominating overall energy consumption the existing improvement potential for standby shows only marginal effect. The decrease in total is related to an expected decrease in stock and VHS in particular. However, the stock forecast is difficult and to some extent questionable. The disk-based technologies for video recording, storage and replay are continuously improving. The hard disk drives (HDD) are getting smaller and lighter and therefore easier to integrate in other products such as the TV or a Set-top Box. It is not clear if stand-alone DVD player/recorder will continue to exist in the long-term.

In terms of performance (and to some extent energy consumption) it is the red or blue laser in the HDD that sets the technical and cost limits to the system. With the trend to high definition and super high definition the data processing and storage (catch) capacity must increase. It is this aspect that currently leads to a rather increase in power consumption then a decrease.

Table 32: Estimated improvement potential BAU/Eco-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total VHS/DVD Equipment	4.2	2.3	2.1	0.3

Figure 19: BAU and Eco-scenarios for VHS/DVD



1.3.1.7 Set-Top-Boxes

■ Current Status

● Status

Simple STB

Simple STBs and STB/PVR⁵⁵ have been investigated within the framework of a EuP Preparatory Study⁵⁶.

- Status: The stock of Simple STBs was 26.2 million units in 2006 with a respective annual electricity consumption of 1.5 TWh/a.
- Trend: The product trend is clearly shifting towards complex STBs. Improvement potential is minimal and mainly related to standby. The electricity consumption of simple STB is assumed to be constant until 2020. In a BAU-scenario, PVR will improve from about 110 to 80 kWh/a per unit between 2005 and 2020 (mainly related to standby).

Complex STB

The EuP Study Lot 18 on Complex STBs just started in October 2007 and will run until end of 2008. *At the point of writing no data on stock or energy consumption were available.* However, based on estimates from previous studies⁵⁷ on the energy consumption of set-top boxes, we can estimate the average power requirement of a set-top box (average including simple and complex set-top boxes) to range between 100 and 200 kWh/a with higher values for PVR types.

Table 33: US estimates of the annual electricity consumption of various STB (2007)⁵⁸

		Cable			Satellite			Stand-alone PVR		
		Active	Off	Total	Active	Off	Total	Active	Off	Total
UEC by Functionality and Operating Mode [kWh/yr]	Analog STB	44	93	138						
	Digital STB	38	84	123	43	70	113			
	HD STB	59	124	182	69	100	169			
	PVR STB	71	127	198	82	139	222	56	180	237
	HD DVR STB	79	145	224	137	223	360			
	Weighted Avg.	43	90	133	49	80	129	56	180	237

⁵⁵ PVR – Personal Video Recorder

⁵⁶ MVV Consulting GmbH and Robert Harrison and Associates Ltd. Source: <http://www.ecostb.com/Introduction>

⁵⁷ CEA – US Consumer Electronics Association

⁵⁸ Consumer Electronics association USA
[http://www.ce.org/pdf/Energy%20Consumption%20by%20CE%20in%20U.S.%20Residences%20\(January%202007\).pdf](http://www.ce.org/pdf/Energy%20Consumption%20by%20CE%20in%20U.S.%20Residences%20(January%202007).pdf)

Table 34: US estimates of the power requirement of different set-top boxes in various modes [Roth, McKenney 2007]⁵⁹

Operating Mode		Cable		Satellite		Stand-alone DVR	
		Active	Off	Active	Off	Active	Off
Power Draw by Functionality and Operating Mode [W]	Analog STB	16	16	n/a	n/a	n/a	n/a
	Digital STB	14	14	13	13	n/a	n/a
	HD STB	22	21	21	18	n/a	n/a
	PVR STB	26	21	25	25	27	27
	HD DVR STB	29	24	42	40	n/a	n/a
	Weighted Avg.	16	15	15	14	27	27

Based on data from the UK market transformation program (UK MTP), we can estimate the annual average consumption of STBs to be about **130 kWh/a per unit for the reference year 2005 (see details below)**. This is a **very rough estimate** as the products present a wide range of power requirements. Use patterns can be assumed to be⁶⁰:

- 4 h/d in on-mode at 15 W
- 20 h/d standby at 15 W

The stock can be estimated based from 2005 sales data from EITO, which total 16,214 units sold in Western Europe (Austria, Belgium, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, and the UK) and assuming an average lifetime of 3.5 years (typically ranges between 3 and 5 years), and assuming this represents about 80% of the EU 25 market, we estimate the stock of set-top boxes to about **70 million units for the whole EU 25 for the year 2005**⁶¹.

• Trends

Set-top boxes have been identified⁶² as a major driver for the increase in electricity consumption with the move to digital TV and broadband communication. The European Union is moving towards the switch to digital TV and the phase-out of analogue broadcasting, meaning that the current stock of analogue TVs will require converter boxes in order to function. At the same time, pay-TV is competing on the market with more sophisticated services and offers, resulting in even more complex set-top boxes, with an increase in the electricity consumption per unit.

⁵⁹ [Roth, McKenney] Kurt W. Roth, Kurtis McKenney: *Energy Consumption by Consumer Electronics in U.S. Residences*, Final Report to the Consumer Electronics Association (CEA), January 2007

⁶⁰ The assumptions on power requirements are based on data from UK market Transformation Program and seem to be rather ambitious

⁶¹ This correlates more or less to the Canalis research company's projection which estimated the number of households with digital TV in Western European countries was already over the 50 million during the first half of 2005 (<http://sunbird.jrc.it/energyefficiency/pdf/EnEff%20Report%202006.pdf>)

⁶² <http://sunbird.jrc.it/energyefficiency/pdf/EnEff%20Report%202006.pdf>

In addition to the digital TV services such as satellite, terrestrial and cable TV, new service providers are starting to offer digital TV and video-on-demand through the telephone lines (DSL modems, power line technology). ICTs and consumer electronics are converging e.g. providers of TV and Internet leading to growing electricity demands. Indeed, this implies that more than one system is always on in each household.

Table 35: EU-25 estimates for STBs

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Simple STB	26.2	57.8	1.5
Complex set top boxes	Data will be available in EuP lot 18	Data will be available in EuP lot 18	Data will be available in EuP lot 18
Total STB Rough estimate	70	130.0	9.1

■ BAU-Scenario

The stock data projections for year **2010** is based on an estimate from a previous European study⁶³ which stated that potentially **over 200 million** of these boxes across the EU - equivalent to one per household – could be installed. Assuming the same penetration rate, and based on the projections in the number of households by EUROSTAT, we assume a **2010 stock of about 210 million units**. We can assume that by 2010 the consumption per unit slightly decreases down to 95 kWh/a because of improvement in the standby mode and also encouraged by The European Code of Conduct on set-top boxes.

In 2020, it can increase up to 125 kWh, because of larger number of complex set-top boxes appearing on the market.

Power requirements estimates from UK MTP 2010

- 4 h/d in on-mode at 15 W
- 20 h/d standby at 10 W

Estimates from UK MTP 2020

- 4 h/d in on-mode at 20 W
- 20 h/d standby at 13 W

⁶³ Paolo Bertoldi, Bogdan Atanasiu: Electricity Consumption and Efficiency Trends in the Enlarged European Union – Status report 2006, Institute for Environment and Sustainability, 2007, online: <http://sunbird.jrc.it/energyefficiency/pdf/EnEff%20Report%202006.pdf>

Table 36: EU-25 Business-as-Usual Scenario until 2020 for STBs

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁶⁴ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Simple STB	26.2	57.8	1.5	109.0	57.1	6.2	13.1	80.4	1.1
Complex STB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total STB Rough estimate	70	130.0	9.1	200.0	100.0	20.0	210	125	26.3

Electr. = Electricity

■ Eco-Scenario

For the Eco-scenario, further improvements are made and following power requirements can be assumed:

Estimates from UK MTP 2010 in a best practice scenario – annual electricity consumption of 78.8 kWh/a per unit

- 4 h/d in on-mode at 14 W
- 20 h/d standby at 8 W

Estimates from UK MTP 2020 in a best practice scenario – annual electricity consumption of 82.5 kWh/a per unit

- 4 h/d in on-mode at 14 W
- 20 h/d standby at 8.5 W

Table 37: EU-25 Eco-Scenario until 2020 for STBs

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Simple STB	26.2	57.8	1.5	109.0	n/a	n/a	13.1	n/a	n/a
Complex STB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rough estimate Total STB	50.0	130.0	7.5	200.0	78.8	15.8	210	82.5	17.3

Electr. = Electricity

⁶⁴ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

■ Summarising table and conclusions

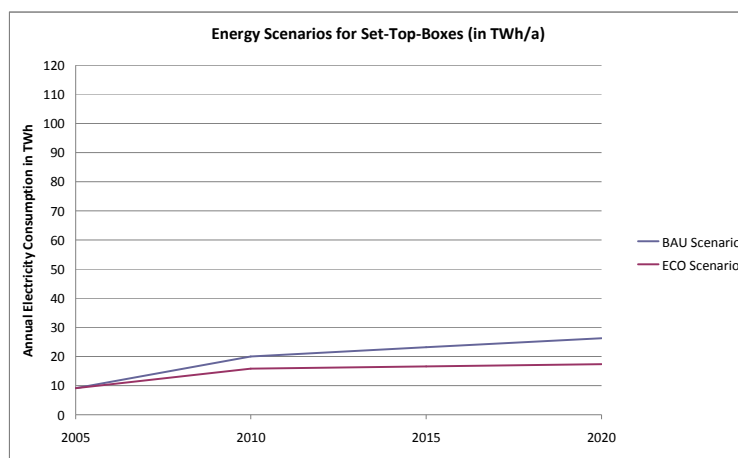
Mains issues from improving the energy efficiency of set-top boxes rely in the **active standby mode** which currently requires as much power as in on-mode and in **power management** which should be developed in order to enable some components in the set-top box to turn off when they are not operating.

Also, it should be noted that in the BAU and BAT scenario developed here, which are very rough estimates, it was not considered that these products might incorporate a very wide range of functionalities in the future: e.g. game consoles, DVD players.

Table 38: Estimated improvement potential BAU/Eco-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Simple STB	1.5	1.1	n/a	n/a
Complex STB	n/a	n/a	n/a	n/a
Total STB Rough estimate	9.1	26.3	17.3	9

Figure 20: BAU and Eco-scenarios for Set top boxes (EU 25 stock electricity use during use phase)



1.3.1.8 Telephones

■ Current Status

• DECT (cordless) telephone⁶⁵

The number of DECT phones in offices and households is 23.8 million in Germany⁶⁶. Extrapolating this would result in 89.1 million DECT phones in EU 25 for the year 2005. The ISI studies states 3.5 W active and 2 W for standby.

• Smart phones⁶⁷

The stock includes line telephones with many additional functions (not included are simple line phones)

- Status: Original figures for Germany in 2004 were 14.2 million units (households: 7.0 million units, offices: 7.2 million units). For the EU-25, we estimate a stock of 75.4 million units and a total energy consumption of 1.36 TWh/a. The energy consumption is assumed to be 4 W in on-mode and 2 W in standby.
- Trend⁶⁸: the number of so-called “smart phones” will increase by about 50% to 115.2 million units, major increases will be within the household sector, the number of smart phones will almost double, whereas the number of smart phones in offices will increase by only 10%.

The German consumer magazine “connect” names 2.59 W as average electricity consumption for DECT phones. Thereby 60% of the electricity is used in standby, 10% during calls and 30% while charging⁶⁹

For the year 2005, the annual electricity use for DECT phones and Smart phones was estimated based on the stock extrapolation from Fraunhofer ISI and an average 3 W over 24 h/d.

Table 39: EU 25 estimates for DECT and Smart Telephones (2005)

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
DECT phones	89.1	26.3	2.3
Smart phones	75.4	26.3	2.0
Total Telephones	164.5	26.3	4.3

⁶⁵ Source: EuP Study Lot 7 (<http://www.ecocharger.org>)

⁶⁶ Source : ISI/CEPE Study

⁶⁷ Source : ISI/CEPE Study

⁶⁸ Source : ISI/CEPE Study

⁶⁹ Connect : http://www.connect.de/themen_spezial/Schnurlostelefone_156345.html

■ BAU-Scenario

The business-as-usual scenario is again based on the stock development extrapolated from the Fraunhofer ISI figures for the year 2010 and 2015. Adequate stock data for the year 2020 could not be obtained. We therefore made the pragmatic assumption that the stock of 2020 is the same as the stock of 2015. The BAU scenario assumes a constant use of 3 W over 24 h/d.

This scenario shows an increase in annual electricity consumption by factor 1.5 (6.3 TWh/a) until 2020 which is related to an increase in stock.

Table 40: EU 25 BAU-scenario until 2020 for Telephones

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁷⁰ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
DECT phones	89.1	26.3	2.3	111.7	26.3	2.9	124.2	26.3	3.3
Smart phones	75.4	26.3	2.0	98.8	26.3	2.6	115.2	26.3	3.0
Total Telephones	164.5	26.3	4.3	210.5	26.3	5.5	239.4	26.3	6.3

Electr. = Electricity

■ Eco-Scenario

For the Eco-Scenario, the stock estimates remain the same. The annual electricity consumption was estimated on the assumption that the average power demand is decreasing by 30% due to improvements in standby technology (e.g. power supply unit). This seems quite realistic keeping in mind similar improvements that have been made in the mobile phone technology. We assume an average of 2 W over 24 h/d.

Table 41: EU 25 Eco-scenario until 2020 for Telephones

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
DECT phones	89.1	26.3	2.3	111.7	17.5	2.0	124.2	17.5	2.2
Smart phones	75.4	26.3	2.0	98.8	17.5	1.7	115.2	17.5	2.0
Total Telephones	164.5	26.3	4.3	210.5	17.5	3.7	239.4	17.5	4.2

Electr. = Electricity

⁷⁰ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

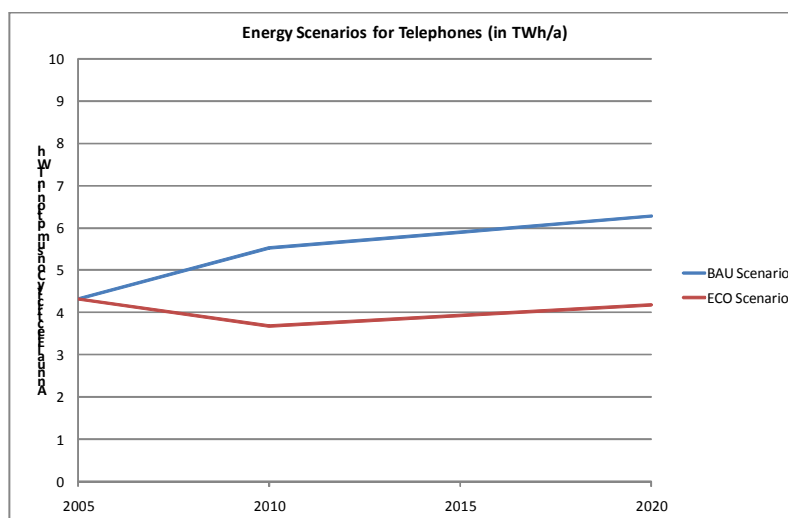
■ Summarising table and conclusions

The scenarios show a considerable improvement potential. The **charger and power supply efficiency is the key technology factor that leads to the improvement**. For DECT telephones the antenna technology is critical as well, in terms of health impacts due to electro smog (electromagnetic waves).

Table 42: Estimated improvement potential BAU/Eco-scenario for telephones (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
DECT phones	2.3	3.3	2.2	1.1
Smart phones	2.0	3.0	2.0	1.0
Total Telephones	4.3	6.3	4.2	2.1

Figure 21: BAU and Eco-scenarios for telephones (EU 25 stock electricity use during use phase)



1.3.1.9 Fax machines

■ Current Status

The EuP Lot 4 Study⁷¹ includes stock data for single function and multi functional facsimile machines from InfoTrends. Annual electricity consumption was calculated on the basis of a constant power consumption of 5.9 W per year (operating 8760 hours/a).

- Status: EU-25 stock in 2005 totalled 20.1 million units with a calculated annual electricity consumption of 1.0 TWh/a.

⁷¹ Source: EuP Lot 4 Study (<http://www.ecoimaging.org>)

- Trend: The number of fax machines will decrease in total by about 30% until 2010 (ISI, EuP Lot 6, EuP Lot 4) and even 70% until 2020 (EuP Lot 4). The number of multifunctional devices (MFD) will slightly increase to about 8 to 9 million units. Energy consumption will be influenced by the facilitation of an effective power management. A networked standby of 3 W or even less is possible.

Table 43: EU 25 estimates for Fax machines (2005)

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Total Fax machines	20.1	51.7	1.0

■ BAU-Scenario

The business as usual scenario uses the stock development from EuP Lot 4. Due to the maturity of the technology it was assumed for this scenario that the energy consumption per units stays the same over the years. We assume therefore an average 5.9 W over 24/d. The scenario clearly indicates the decline in stock and related decline in energy consumption. We can, however, assume that printer-based MFD take up a part of the fax volume.

Table 44: EU 25 BAU-scenario until 2020 for Fax machines

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁷² (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Fax machines	20.1	51.7	1.0	13.3	51.7	0.7	9.0	51.7	0.5

Electr. = Electricity

■ Eco-Scenario

The electricity consumption in the Eco-scenario is calculated with a constant power consumption of 3 W over 24h/d.

Table 45: EU 25 Eco-Scenario until 2020 for Fax machines

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Fax machines	20.1	51.7	1.0	13.3	26.3	0.3	9.0	26.3	0.2

Electr. = Electricity

⁷² This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

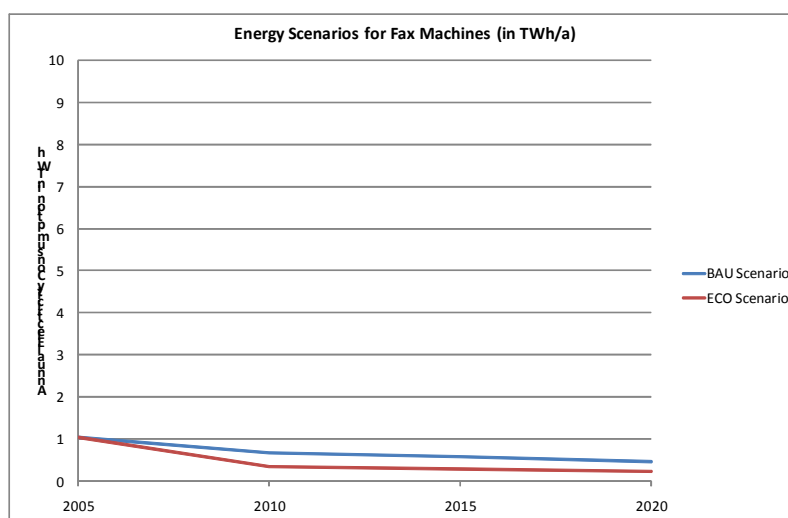
■ Summarising table and conclusions

The ubiquitous utilisation of the PCs and the internet (e-mails) is continuously leading to a decline of this product category. The respective energy consumption will also change accordingly.

Table 46: Estimated improvement potential BAU/ECO-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total Fax machines	1.0	0.5	0.2	0.3

Figure 22: BAU and Eco-scenarios for Fax machines (EU 25 stock total electricity use during use phase)



1.3.1.10 Modems⁷³

■ Current Status

The stock includes dial-up modems and broadband modems (with and without W-LAN capabilities).

- Status: We assume a stock of 68.7 Million units with an annual electricity consumption of 4.1 TWh/a (6.8 W average power consumption). The electricity consumption per unit was calculated based on the following the use pattern from EuP Lot 7 study:
 - 8.45 W rated output with 70% efficiency
 - 3 h/d 100% load
 - 21 h/d 50% load

⁷³ Source: EuP Lot 6 study (<http://www.ecostandby.org>)

- Trend: The development of wide broadband optical cable and wireless network technologies will have an effect on the technical parameters and utilisation of modems.

ADSL modems are recent developments using coded orthogonal frequency division modulation (DMT). Cable modems use a range of frequencies originally intended to carry RF television channels. Multiple cable modems attached to a single cable can use the same frequency band, using a low-level media access protocol to allow them to work together within the same channel. Typically, 'up' and 'down' signals are kept separate using frequency division multiple access. New types of broadband modems are beginning to appear, such as double-way, satellite, and power-line modems. Broadband modems should still be classed as modems, since they use complex waveforms to carry digital data. They are more advanced devices than traditional dial-up modems as they are capable of modulating/demodulating hundreds of channels simultaneously. Many broadband modems include the functions of a router with Ethernet and WiFi ports and other features such as DHCP, NAT and firewall features.

In the future, software defined radio (SDR) modems could be used. With the proliferation of wireless communication, future devices will need to support multiple air interfaces and transmission (signal modulation) formats. SDR technology enables such functionality in wireless devices by using a reconfigurable hardware platform across multiple standards. However, SDR currently requires extensive processing power to realize their promised portability of waveforms and re-configurability (e.g. currently available in military applications).

Table 47: EU-25 estimates for Modems (2005)

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Total Modems	68.7	59.5	4.1

■ BAU-Scenario

The stock development of the BAU-Scenario is based on the annual growth of 9.4% from 2005 to 2010 and 5% from 2010 to 2020 from EuP Lot 7. The energy consumption per device stays the same. The business as usual scenario shows a sharp increase in energy consumption due to the assumed stock development. But we have to assume that not only the stock increase will lead to higher energy consumption related to modems. It is the use intensity that will have an equally important effect. Bandwidth enhancement will lead to rapid increase in data traffic with longer on-mode hours.

Table 48: EU 25 BAU-scenario until 2020 for Modems

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁷⁴ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Modems	68.7	59.9	4.1	107.7	59.9	6.4	175.4	59.5	10.4

Electr. = Electricity

■ ECO-Scenario

The ECO-Scenario uses the same stock model as the BAU-Scenario. For the electricity consumption per unit, 25% improvement in 2010 and 2020 in comparison to the year 2005 was assumed. The improvement of 25% is quite arbitrarily chosen and based on the general assumption that advanced micro- and optoelectronics need to reduce power consumption in order to operate efficiently on this physical layer. The eco-scenario still indicates an increase by almost factor 2 until 2020.

Table 49: EU 25 Eco-Scenario until 2020 for Modems

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Modems	68.7	59.9	4.1	107.7	44.6	4.8	175.4	44.6	7.8

Electr. = Electricity

■ Summarising table and conclusions

The difference in the two scenarios is a factor 2 or 3 increase due to the assumed stock increase.

Table 50: Estimated improvement potential BAU/ECO-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total Modems	4.1	10.4	7.8	2.6

⁷⁴ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

■ BAU-Scenario

The stock development of the BAU-Scenario is based on the assumption that in 2010 every inhabitant of EU-27 (492.8 inhabitants) has 2 mobile phones and in 2020 3 mobile phones (phone/internet capable multimedia mobiles) per inhabitant (496.4 million inhabitants). The energy consumption per device stays the same. For the use pattern it is assumed that the devices are 1 h/d loaded with 4 W rated output and 66% efficiency and stay in no load 10 h/d with no-load losses of 0.3 W. This is a rather conventional scenario for a single mobile phone. But because we apply this pattern to all mobile phones (also in secondary use) it seems justified.

Table 52: EU-25 BAU-scenario until 2020 for Mobile phones

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit ⁷⁶ (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Mobile phones	819.0	3.3	2.7	985.6	3.3	3.3	1,489.2	3.3	4.9

Electr. = Electricity

■ Eco-Scenario

For the Eco-scenario it is assumed that the devices do not cause any no-load losses. Thereby the electricity consumption per unit drops to 2.2 W.

Table 53: EU 25 Eco-scenario until 2020 for Mobile phones

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Total Mobile phones	819.0	3.3	2.7	985.6	2.2	2.2	1,489.2	2.2	3.3

Electr. = Electricity

■ Summarising table and conclusions

The energy consumption related to mobiles is difficult to assess due to the complexity of technical interaction of the mobile phone with the network as well as the multitude of possible use patterns. An actual worst case scenario is always on and high on-line utilisation. This would lead to frequent charging (or always charging throughout the night) which is the source of energy consumption. On the other hand are mobile phones real technology drivers. The trend to miniaturise full multimedia capability has lead to a good level of energy efficiency per device. It is essential that this trend

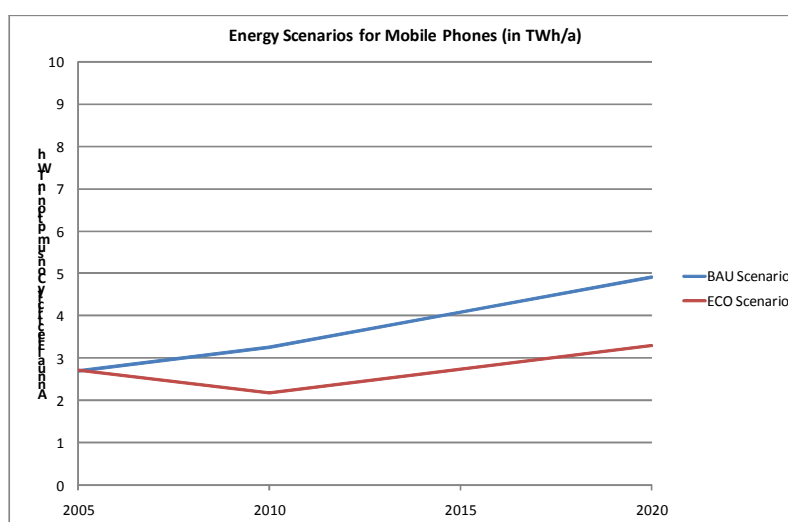
⁷⁶ This per unit electricity consumption refers to an **average product in stock** and does not represent the electricity consumption of a new product introduced on the market for a given year

continues: the danger of overcompensating efficiency gains by new functionalities and higher performance has been seen in the past.

Table 54: Estimated improvement potential BAU/ECO-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total Mobile phones	2.7	4.9	3.3	1.6

Figure 24: BAU and Eco-scenario for mobile phones (EU 25 stock total electricity use during use phase)



1.3.2. ICT INFRASTRUCTURE

The assessment of the annual electricity consumption for the European stock of ICT infrastructure includes the following equipments:

- Server and data centres

This category contains small to large servers and their respective infrastructure including air condition systems, ventilation systems, lighting systems, switches, and uninterruptible power supplies (UPS).

- Core Telecom Networks and TV/radio Broadcasting

This category contains copper or optical fibre telecommunication lines with respective terminals, router, and switches. We also cover Radio/TV broadcast equipment including radio relays, directorial radio antennas, etc.

- Cellular Phone Networks

This category contains mobile phone telecommunication of the 2nd (GSM/GPRS) and 3rd generation (UMTS/WCDMA) with base transceiver stations (node B), main

switch controls, and others network components including their infrastructure (cooling etc.).

- Wireless Local Area Networks

This category contains WLAN equipment such as base stations and repeaters.

1.3.2.1 Server and Data Centres

- Current Status

Only in the recent years, the research has touched the issue of energy consumption related to servers and their infrastructure in data centres. Economic data regarding product stock are not adequately available. In the following paragraphs, we have compiled most recent literature on this issue.

The installed base of servers in the EU is calculated based on global and regional market data based on latest research results from the United States (Koomey 2007)⁷⁷ and Germany (Fichter 2007)⁷⁸.

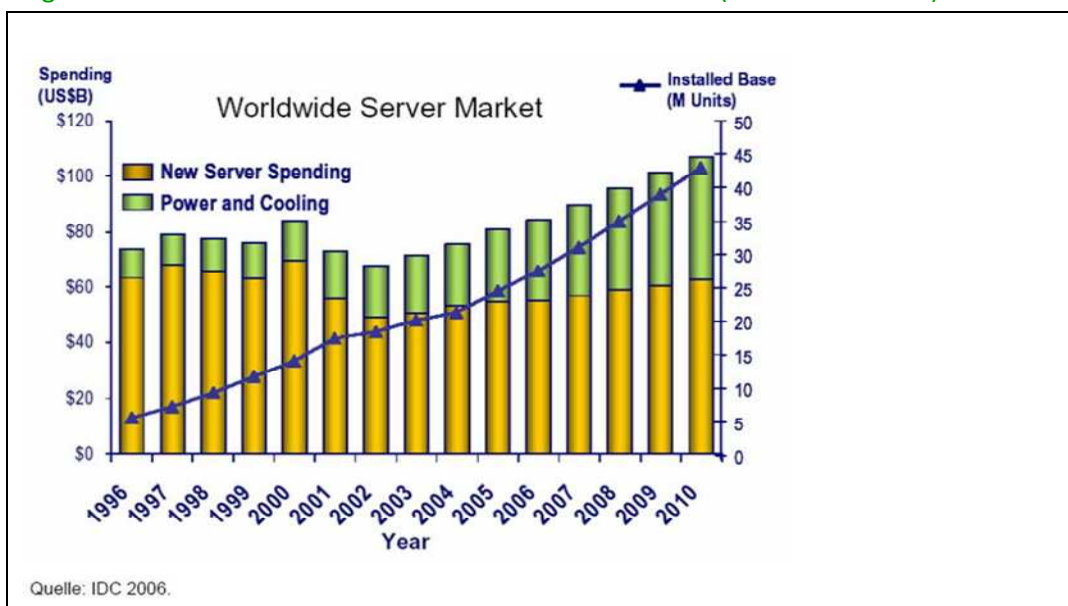
According to Koomey, who is detailing a market survey of IDC (2006), the worldwide number of servers increased from 14 million units in 2000 to 27 million in 2005 and is expected to reach to 43 million units by the year 2010 (Figure 25). IDC estimates the installed base using data on shipments and equipment lifetimes derived from manufacturer reporting and market surveys. Three different server types are defined: volume servers, mid-range servers and high-end servers. IDC defines these server classes based on the cost of the system: volume servers cost less than \$25,000 per unit, mid-range systems cost between \$25,000 and \$500,000 per unit, and each high-end system costs more than \$500,000 per unit. Blade servers, which are an important component of recent growth in the total numbers of servers, are subsumed under the volume server class, with one blade counting as one server⁷⁹.

⁷⁷ Koomey, Jonathan G. (2007): *Estimating Total Power Consumption By Servers In The U.S. And The World*, Lawrence Berkeley National Laboratory, CA USA. Study is available online: <http://www.enterprise.amd.com/Downloads/svrpwrusecompletefinal.pdf>.

⁷⁸ Fichter, Klaus (2007): *Zukunftsmarkt Energieeffiziente Rechenzentren* (in English: Future market energy-efficient data centre), Borderstep Institute for Innovation and Sustainability, Berlin Germany. Study is available online: <http://www.borderstep.eu/pdf/Studie%20Zukunftsmarkt%20energieeffiziente%20Rechenzentren%20final-2007.pdf>.

⁷⁹ Koomey (2007) discussed the IDC data in detail. He noticed (page 3): «Another important category of servers that may be underrepresented in the IDC data is that of custom servers used by some large Internet companies (such as Google) that are ordered directly from the manufacturer as personal computer motherboards but are then used as servers. One estimate reported in the New York Times in June 2006 (Markoff and Hansell 2006) was that Google owns about 450,000 servers worldwide. It is not known whether all of these servers are the custom-designed units described above and how many are standard servers that would have fallen under the IDC “volume server” category. If all of these servers were added to the volume server category for the world in 2005 they would increase the volume server

Figure 25: World server market – installed base until 2010 (Source: IDC 2006)



Fichter (2007) builds up on these data and provides further estimates for the number of servers and data centres in the EU based on shipment data from EITO (2007, 230). Fichter calculated the EU server stock based on the common ratio between “shipment” and “installed base” of servers (see also Koomey 2007, p. 21). According to this formula the installed base is four times the number of the shipment figures. Fichter (2007) calculated the 2007 installed base of servers in the EU to be 7.56 million units which is an average of 23 servers per data centre. Fichter does not provide a complete structure of server distribution for Germany or Europe. However, he refers to a recent study of U.S. EPA (2007) which provides respective data for the United States (see Table 55).

Table 55: Distribution of servers according to facilities

Server class	% of servers installed in:					Total
	Server closets	Server rooms	Data centers			
			Localized	Mid-tier	Enterprise-class	
Volume	17%	20%	17%	15%	30%	100%
Mid-range	0%	5%	16%	14%	65%	100%
High-end	0%	0%	16%	14%	71%	100%

Quelle: U.S. EPA 2007, 35 auf Basis von Bailey et al. 2007 und IDC 2007.

A breakdown of total electricity consumption for different servers and infrastructure equipments is provided by EPA (2007) for U.S. data centres for the years 2000 and 2006 (see Table 56). The site infrastructure (i.e. servers infrastructure) including air conditioning, uninterruptible power supply, and lighting has a considerable impact on

installed base by 1.7%. It is also not known how many other companies have followed Google’s lead in purchasing such custom designed “motherboard servers”.

total energy consumption and should therefore always be considered in the assessments⁸⁰.

Table 56: Ratio of servers and infrastructure electricity consumption (US EPA 2007, p.26)

End use component	2000		2006	
	Electricity use (billion kWh)	% Total	Electricity use (billion kWh)	% Total
Site infrastructure	14,1	50%	30,7	50%
Network equipment	1,4	5%	3,0	5%
Storage	1,1	4%	3,2	5%
High-end servers	1,1	4%	1,5	2%
Mid-range servers	2,5	9%	2,2	4%
Volume servers	8,0	29%	20,9	34%
Total	28,2		61,4	

Based on the data provided by Koomey (2007), Fichter (2007), and U.S. EPA (2007) we estimated the EU server stock and respective annual electricity consumption for the **reference year 2005** (see Table 57):

- **EU total (2005) servers:** **6.45 million units**
- **EU total (2005) servers:** **14.4 TWh/a**
- **EU total (2005) servers infrastructure:** **14.7 TWh/a**

For the reference year 2007 and EU total we estimated following server stock and respective energy consumption based on the same sources:

- EU total (2007) servers: 7.56 million units
- EU total (2007) servers: 16.9 TWh/a
- EU total (2007) servers infrastructure: 17.1 TWh/a

In accumulated electricity consumption of server and data centres in EU total for the year 2007 is according to the studies of Koomey and Fichter approx. 34.0 TWh/a.

⁸⁰ In Task 2, section 2.1.2.6 a case study illustrates the interactions between server infrastructure and HVAC systems and the significance of the HVAC equipment in terms of energy consumption.

Table 57: Annual Electricity Consumption of Servers and Infrastructure (2005)

Product Servers	Product Stock (in million units)	Energy consumption server (in TWh/a)	Energy consumption incl. cooling / aux.	Data Source
high-end server (USA 2005)	0,02	1,50	3,00	Koomey 2007
mid-range server (USA 2005)	0,39	2,10	4,20	Koomey 2007
volume server (USA 2005)	9,90	19,00	38,00	Koomey 2007
Total (USA 2005)	10,31	23,00	45,00	Koomey 2007
high-end server (world wide 2005)	0,06	4,00	8,00	Koomey 2007
mid-range server (world wide 2005)	1,26	7,00	13,00	Koomey 2007
volume server (world wide 2005)	25,96	50,00	101,00	Koomey 2007
Total (World 2005)	27,28	61,00	123,00	Koomey 2007
EU (2005) calculated	6,45	14,41	29,06	BIO/IZM 2007
EU (2007)	7,56	16,90	34,00	Fichter (2007)
World (2007)	32,00	71,50	144,20	Fichter (2007)

According to another recent study by “The Efficient Servers Consortium”⁸¹ the electricity consumption of servers in Western Europe (EU-15 plus Switzerland) in 2006 to be 14.7 TWh/a. This is basically the amount that we have estimated for servers in EU total for the reference year 2007. The Efficient Servers Consortium estimated furthermore the energy consumption of complete data centres in EU-15 plus Switzerland, including storage, network components and infrastructure, to be 36.9 TWh/a. The study concluded that there was an effective increase of energy consumption related to servers and data centres by almost 40% in comparison to the year 2003. In comparison to the first results we have to assume an even higher overall impact of servers and their infrastructure for EU total.

The study by the E-Server Consortium provides following data for 2006:

- EU-15 plus CH (2006) servers: 6.77 million units
- EU-15 plus CH (2006) servers: 16 TWh/a
- EU-15 plus CH (2006) servers infrastructure: 23.6 TWh/a

For the 2006 EU total of servers and respective infrastructure (data centres) we make the following pragmatic assumptions based on the literature discussed above.

⁸¹ Schäppi, Bellosa, Przywara, Bogner, Weeren, Anglade: *Energy efficient servers in Europe – Energy consumption, saving potentials, market barriers and measures, Part I + II (Draft)*, The Efficient Servers Consortium (Consortium E-Server), November 2007

- EU total (2006) servers: 7.0 million units
- EU total (2006) servers: 16.0 TWh/a
- EU total (2006) servers infrastructure: 20.0 TWh/a
- EU total (2006) server + infrastructure: **36.0 TWh/a**

Table 58: EU 25 electricity consumption of Servers and infrastructure (2005)

Product	Estimated EU Stock (million units)	Estimated Electricity use per unit (kWh/a)	Estimated Electricity Use (TWh/a)
Servers	6.45	2232.6	14.4
Infrastructure	n/a	n/a	14.7
Total data centres	n/a	n/a	29.1

• Trend

The growing number of small volume servers as well as mid-range servers in data centres will result in an overall increase of total energy consumption in the mid-term. There is a good potential for improving the energy efficiency on a system level⁸². The data centre infrastructure provides a high potential particularly regarding the thermal management and power supply conditions.

Figure 26: Energy consumption – analysis per price range (2006) [Consortium E-Server]

	% of stock	% of total power consumption
High End (>500k\$)	<1	10
Mid-range (25-500k\$)	4	12
Volume (10-25 k\$)	6	10
Volume (6-10 k\$)	5	5
Volume (3-6 k\$)	50	40
Volume (<3 k\$)	35	24

According to the Consortium E-Server, the energy consumption of data centres will increase but the trend towards virtualisation⁸³ is expected to slow down the annual increase of shipments. The study provides three different scenarios for the development until 2011.

The business-as-usual scenario and the moderate efficiency scenario both result in increased energy consumption of data centres compared to 2006. For 2011, the E-

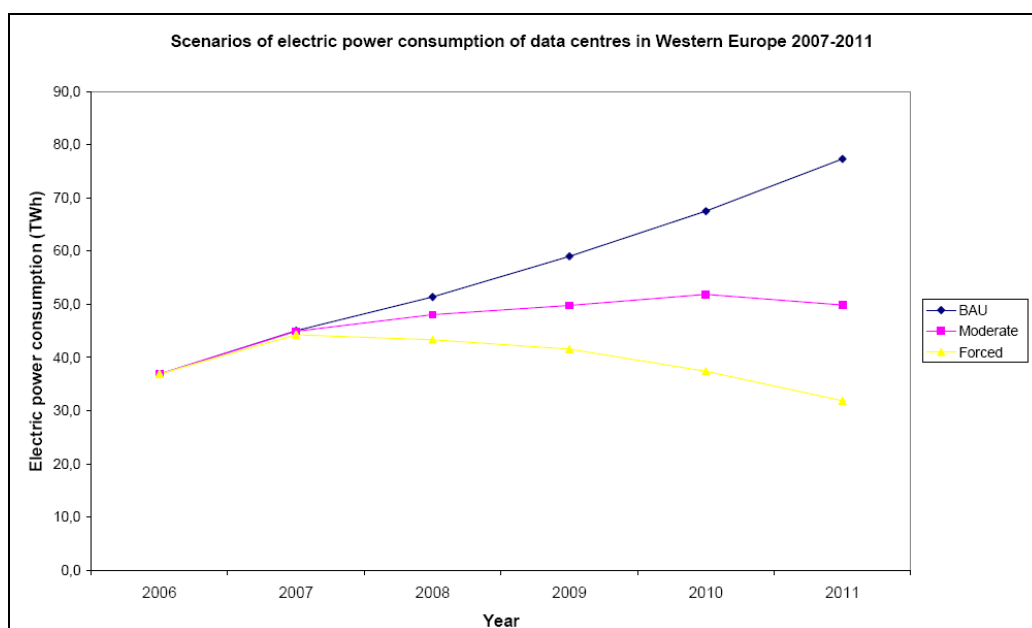
⁸² Fichter, Klaus (2007): *Zukunftsmarkt Energieeffiziente Rechenzentren* (in English: Future market energy-efficient data centre), Borderstep Institute for Innovation and Sustainability, Berlin Germany. Study is available online:
<http://www.borderstep.eu/pdf/Studie%20Zukunftsmarkt%20energieeffiziente%20Rechenzentren%20final-2007.pdf>.

⁸³ Virtualisation is the practice of running a layer of software on a server that allows multiple operating systems and environments to run on the same piece of hardware as if they were separate physical servers. It allows computing resources to be used more efficiently and also allows much greater flexibility in managing and allocating these resources (optimisation of data centre use)

Server Consortium gives a business-as-usual scenario which is based on the expected market development by IDC. This Scenario includes “consolidation by virtualisation assuming a factor of 5 but expecting only low degrees of implementation for power management and energy efficient hardware. The increase of energy efficiency by use of highly efficient hardware was set to 25 % for the years 2007–2011, with implementation levels ranging from 5 to 25 %. Efficiency gains by power management of CPUs and disks were set to 20 respectively 5 % with degrees of implementation between 5 and 30 % from 2007 to 2011”.

Only the “forced efficiency scenario” leads to a slightly lower energy consumption of data centres in 2011 (see Figure 27), but, according to the authors, this scenario is unlikely to happen and would require a mix of different measures, e.g. minimum efficiency standards.

Figure 27: Scenarios for the electricity consumption of data centres in Western Europe [Consortium E-Server]



■ BAU-Scenario

For the purpose of this study, we make a pragmatic business-as-usual scenario based on the findings from existing studies. In general, we assume a further increase in server stock and the related infrastructure. The number of servers is increasing by 1 million units each year which equals roughly 15% annual growth of the market. This has been the annual increase in servers worldwide in the past 5 to 10 years.

The individual energy consumption per server remains the same as in the reference year 2005. The reason behind this assumption is the trend that the overall performance improvements of servers (data processing/storage capacity) and infrastructure is overcompensating the energy efficiency gains of improved processor technology etc.

Regarding the energy consumption of the infrastructure we make the following assumptions: in 2005 and 2010, the energy consumption ratio of servers to infrastructure remains the same and is 45% (servers) and 55% (infrastructure). We also assume that the energy efficiency of the infrastructure will increase slightly and achieve by 2020 a ratio of 50% servers and 50% infrastructure.

The resulting business-as-usual scenario shows a considerable increase of factor 2.7 in overall energy consumption related to servers and data centres until 2020. The increase from 36 TWh/a (2006) to 96 TWh/a (2020) makes the servers and their infrastructure a main energy demand contributor in the field of ICT. We could even assume that the server stock is further increasing particularly in small volume servers.

Table 59: EU 25 BAU-scenario until 2020 for Servers / Data Centres

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Servers	6.45	2232.6	14.4	11.0	2286	25.1	21.0	2286	48.0
Infra- structure	n/a	n/a	14.7	n/a	n/a	30.7	n/a	n/a	48.0
Total data centres	n/a	n/a	29.1	n/a	n/a	55.8	n/a	n/a	96.0

Electr. = Electricity

■ Eco-Scenario

For the Eco-Scenario we reflect on the “moderate efficiency-Scenario” from the E-Server Consortium as well as improvement potentials (particular for infrastructure) that have been outlined by the study of Fichter (2007). This moderate scenario is expected to occur if a moderate set of measures are set to encourage the trend towards virtualisation, use of efficient hardware as well as power management at the CPU and disk level and improvement of some components at infrastructure level (e.g. procurement guidelines, financial incentives, information on best practices and awareness campaigns).

We take the same stock development assumption as in the previous scenario. In terms of servers, we do not assume any improvements until 2010. By 2020, however, we assume that the overall energy consumption will be improved by 20% in comparison to the reference value of the year 2010. Regarding the infrastructure, we assume the following servers/infrastructure ratios:

- 2005: 45% servers 55% infrastructure
- 2010: 50% servers 50% infrastructure
- 2020: 55% servers 45% infrastructure

The results of this Eco-scenario are shown below. The overall increase in energy consumption is with factor 1.9 more moderate and reflects the improvement in technology and energy management (infrastructure). By 2020 the electricity consumption of data centres total 69.8 TWh/a.

Table 60: EU 25 Eco-scenario until 2020 for Servers / Data Centres

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Servers	6.45	2232.6	14.4	11.0	2286	25.1	21.0	1829	38.4
Infra- structure	n/a	n/a	14.7	n/a	n/a	25.1	n/a	n/a	31.4
Total data centres	n/a	n/a	29.1	n/a	n/a	50.2	n/a	n/a	69.8

Electr. = Electricity

■ Summarising table and conclusions

The servers and their infrastructure are becoming a major energy contributor in the field of ICT. This trend is driven by the rapid increase in digital data traffic and the resulting necessity for data processing and data storage. The current capacities will have to increase in order to comply with the growing demand. And although the energy efficiency of single servers or systems is improving on a good level, the sheer demand on server capacity will lead to an overall increase. Despite hardware and power management improvement, the overall efficiency can only be improved through an efficient handling of data and a sufficient use of data. Software development has to address these aspects of data reduction.

Business initiatives such as the ones listed below show that the industry is already moving in the direction of more efficient servers and data centres:

- Intel announces possible 16-18% energy saving technologies for data centres (micro processors and modern AC configuration)⁸⁴
- HP announced that it is committed to reduce its global energy use by 20 percent by 2010. To accomplish this reduction below 2005 levels, HP commits to deliver energy-efficient products and services to customers and institute energy-efficient operating practices in its facilities worldwide. It announces possible energy cost

⁸⁴ Whitepaper: *Intel® Eco-Rack Achieving 16-18% total power savings with a server rack designed for excellence in power efficiency*, Intel Corporation, 2007, online available: <http://download.intel.com/technology/eep/ecorackwp.pdf>

savings of up to 60% through the implementation of various solutions such as “dynamic smart cooling” or enhanced disk storage systems⁸⁵

- IBM also proposes solutions towards “greener data centres” such as the Cool blue and Big blue initiatives⁸⁶
- Google announced that their data centres use half as much energy as a typical industry data centre to power the same amount of computing. This improvement was achieved over industry standards through the use of increasingly efficient power supplies and evaporative cooling technology.⁸⁷)
- Green grid initiative (association of IT professionals) encourages more efficient data centres – It has published guidelines for more energy efficient data centres and announces possible savings between 20 and 50% of the total energy consumption of the data centre.⁸⁸

Table 61: Estimated improvement potential BAU/ECO-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Servers	14.4	48.0	38.4	9.6
Storage, infrastructure, etc.	14.7	48.0	31.4	16.6
Total Data Centres	29.1	96.0	69.8	26.2

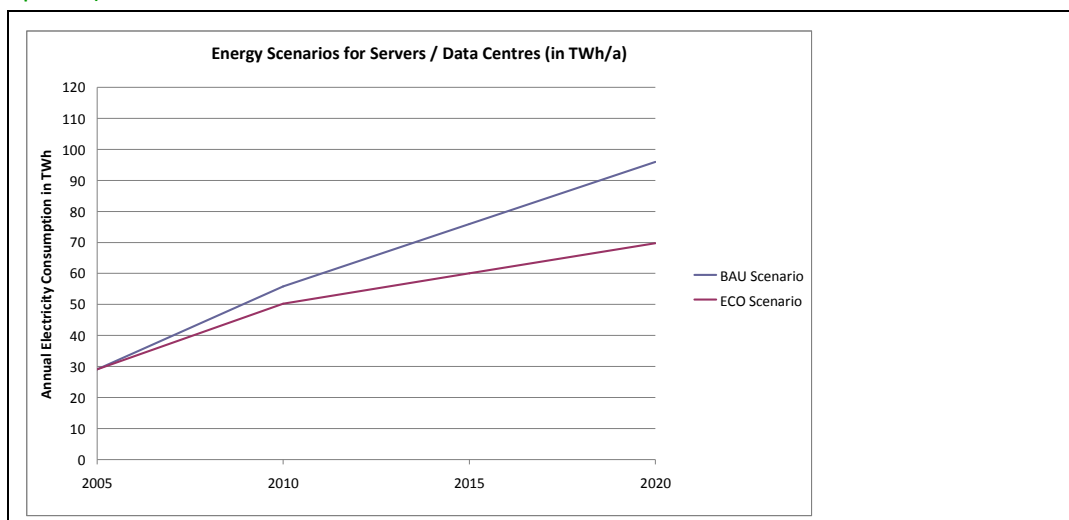
⁸⁵ HP: <http://h71028.www7.hp.com/enterprise/cache/331475-0-0-0-121.html>
<http://www.hp.com/hpinfo/newsroom/press/2007/070328a.html>

⁸⁶ IBM : http://www-03.ibm.com/systems/optimizeit/cost_efficiency/energy_efficiency/technology.html

⁸⁷ Google : <http://www.google.com/corporate/green/energy/reducing.html>

⁸⁸ The Green Grid : <http://www.thegreengrid.org>

Figure 28: BAU and Eco-scenario for servers and data centres (electricity use during use phase)



1.3.2.2 Core Telecom Networks and TV/Radio Broadcasting

■ Current Status

The core telecom networks on the one hand and the TV/radio broadcasting networks are the backbones of modern telecommunication. From a historical perspective, wired (telephony) and radio (broadcasting) networks have been developed by the same business entities, mostly the national post and telecommunication providers. Today's telecom networks include copper and optical fibre lines (cables) with data/signal transmission components such as router, switches, and multiplexer. The broadcasting infrastructure includes satellite and terrestrial transmitter/antenna systems as well as links to the core telecom network. In order to estimate roughly the order of magnitude of the energy consumption related to this core telecom (wired) and broadcasting (radio) infrastructure we have investigated annual reports of the five leading European telecom companies including the British, German, French, Italian and Spanish Telecom.

Based on annual report data of these five companies the EU total electricity consumption can be estimated to be **14.3 TWh for the year 2005**. We assumed that 80% of total electricity consumption is related to network infrastructure and that there is no significant variation between 2005 and 2007. We also assumed that these five companies represent 70% of EU 25.

Table 62: Energy consumption of the five leading telecommunication companies in Europe

Country		Energy consumption on network [GWh]	Energy consumption total [GWh]	Source	available at
Spain	Telefonica Europe total 2006		1.719,60	Corporate Responsibility Report 2006, Telefonica S.A.	http://www.telefonica.es/rc2006/telefonica/informe_rc/docs/corporativo/RC2006_ENG.pdf
Germany	Telekom Konzern total without USA 2006		3.854,83	Corporate Responsibility - Daten und Fakten 2007, Deutsche Telekom AG	http://www.download-telekom.de/dt/StaticPage/47/47/60/CR_Daten_Fakten_2007.pdf_474760.pdf
UK	British Telecom	1.992,00	2.619,00	BT's Sustainability Report 2007, BT Group	http://www.btplc.com/Societyandenvironment/Socialandenvironmentreport/pdf/2007/FullReport.pdf
Italy	Telecom Italia Group		2.571,43	Sustainability Section extract from 2006 Annual Report, Telecom Italia S.p.A.	http://www.telecomitalia.it/sostenibilita2006/English/Download/TI-2006-bilancio-sostenibilita.pdf
France	Telecom France		1.724,00	Rapport de responsabilité d'entreprise 2006, Group France Telecom	www.francetelecom.com/fr/groupe/responsabilite/publications/att00022872/1005_0703399_FT_DD.pdf
Sum		9.991,09	12.488,86		
Total EU-25		14.272,98	17.841,23		EU-5 calculated as 70% of EU-25

■ Trends

The evolution of the core telecom network from copper wire (electronic) to optical fibre (photonic) is ongoing. The conventional networks are reaching already their limits and the demand on even higher communication capacity (more bandwidth) grows. The data rates of the internet are scaling with the advances in laser, optical fibres, and coding technologies. According to the European Technology Platform Photonics²¹ the challenge of the next decade is to create a network capability that supports bandwidth growth to 100-1000 times that of today's "broadband service. Bandwidth and data storage demands will grow inexorably. According to a recent report by OIDA (Optoelectronic Industry Development Association) the following trends are expectable in the next decade:

- 2015 European citizen will have at home the access to 1Gbps per user
- 2015 European metropolitan networks will have average 10Gbps bit rate
- 2015 European core or backbone network will have 40Gbps bit rate
- 2015 total transmission capacity per carrier will be in the 100Tbps range

This network evolution (demand on bandwidth) requires continuous efforts in the field of terminals, efficient modulation (format/coding), amplification, new optical fibres, mitigation of impairments, and equalisation. The general trend is towards an all-IP communication network. In large Asian metropolis such as Hong Kong, Seoul, Tokyo and Singapore, but also in North America we see a strong trend towards extending the bandwidth of the optical fibre into the immediate user's periphery. The promoters of FTTH (Fibre To The Home) see in this approach the chance to overcome the bottleneck

of the “last mile”.⁸⁹ Due to regulatory issues in Europe mainly Sweden and Italy are only following this trend.

Concerning the energy consumption of the growing network demand we have to assume a general increase. Although low power is mandatory for subscriber interfaces, where extensive battery provision must be avoided, the new broadband network architecture which is connecting conventional telecom networks with households, public places, or mobile application (car navigation), will lead to higher energy consumption.

The TV/radio broadcasting infrastructure has been influenced in the past years by the shift from analogue to digital. We see a merger of conventional broadcasting (via terrestrial radio or satellite) with IP-based core telecom (cable) networks. With high definition TV (HDTV) and subsequent ultra high definition TV broadcasting is a strong technology driver influencing infrastructure equipment as well as end-user-devices. The performance requirements towards data processing, coding and encryption in conjunction with HDTV are rapidly increasing. This trend at least on the currently technical level is leading to higher energy consumption of devices.

Table 63: EU 25 estimates for Telecom Network (2005)

Product	Estimated Electricity Use (TWh/a)
Total Telecom Network	14.3

■ BAU-Scenario

For the business as usual scenario we assume as similar increase in telecom network related energy consumption as it was the case of servers. This increase is related to the growing optical network architecture (switches, repeater, or terminals) and the connecting of the “last mile” with the backbone network. We could not obtain literature or data on this issue. We therefore simply assume that electricity consumption of the network is increasing by factor 1.5 until 2010 and 2.5 until 2020.

Table 64: EU 25 BAU-scenario until 2020 for Telecom Network

	2005 (EU-25 estimates)	2010 (EU-25 estimates)	2020 (EU-25 estimates)
	Electr. Use (TWh/a)	Electr. Use (TWh/a)	Electr. Use (TWh/a)
Total Telecom Network	14.3	21.4	35.8
<i>Electr. = Electricity</i>			

⁸⁹ European FTTH Council, in the internet: <http://www.europeanftthcouncil.com>

■ Eco-Scenario

As for the Eco-scenario a similar pragmatic approach is taken. We again assume that electricity consumption of the telecom network is increasing by a factor of 1.5 until 2010 and by a factor of 2 until 2020.

Table 65: EU-25 Eco-scenario until 2020 for Telecom Network

	2005 (EU-25 estimates)	2010 (EU-25 estimates)	2020 (EU-25 estimates)
	Electr. Use (TWh/a)	Electr. Use (TWh/a)	Electr. Use (TWh/a)
Total Telecom Network	14.3	21.4	28.8

Electr. = Electricity

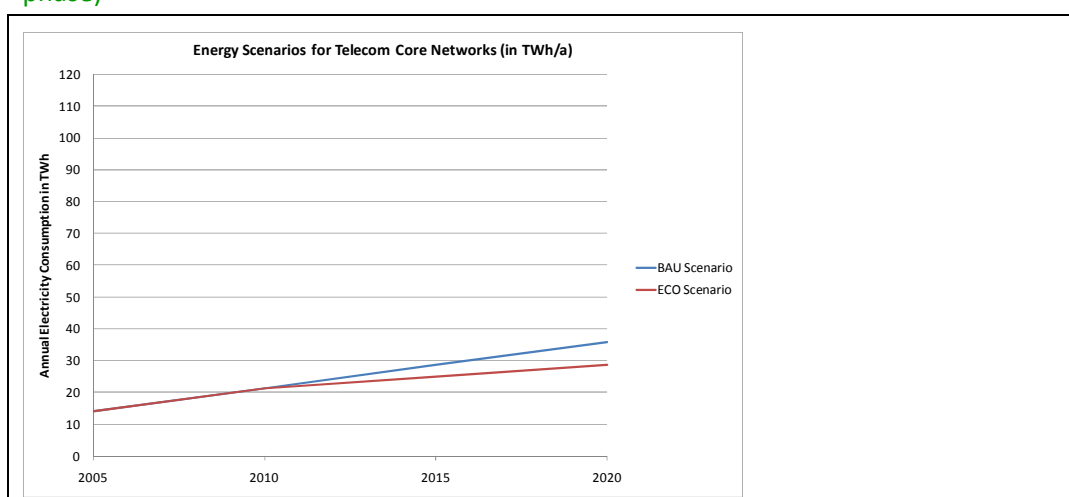
■ Summarising table and conclusions

The estimates on energy consumption related to telecom networks in Europe are very problematic due to missing data. It is important to pay attention to these infrastructure aspects in the future. It is recommended to have further investigations on this issue.

Table 66: Estimated improvement potential BAU/Eco-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total Telecom Network	14.3	35.8	28.8	7.0

Figure 29: BAU and Eco-scenarios for telecom core networks (electricity use during use phase)



1.3.2.3 Mobile Phone Network

■ Current Status

Comprehensive data regarding the total energy consumption of the cellular phone network infrastructure are not available for the EU. Two previous German studies were used– Fraunhofer ISI/CEPE (2003) “Energy Consumption of ICT in Germany up to 2010” and the German NIK Project (2004) “Sustainability in the Information and Communication Technologies”⁹⁰ – which calculated the electricity consumption related to second and third generations of cellular phone networks in Germany. The latter study reflects the ISI/CEPE results and provides modified data based on an industry survey. According to the NIK project’s final report on the focus topic of mobile communication (Stobbe 2004)⁹¹, the electricity consumption of the German cellular phone network accumulates with a conventional improvement scenario to 2.98 TWh/a for the reference year 2005. The NIK project differentiated four types of cellular radio network equipment:

- 2nd Generation (GSM) cellular phone network equipment:
 - GSM base transceiver stations (BTS) on the first level
 - GSM main switch controls (MSC) on the second level
- 3rd Generation (UMTS) cellular phone network equipment⁹²:
 - UMTS base transceiver stations (Node B) on the first level
 - UMTS radio network controller (RNC) on the second level

Based on this figure we have calculated the total energy consumption of the European cellular phone network.⁹³ The energy consumption of the base transceiver stations includes site infrastructure such as air conditioning and was calculated with 40% of total. The resulting 2005 annual electricity consumption in the EU is **13 TWh** (see Table 67 and Table 68).

• Trends

The total energy consumption related to cellular phone networks will increase in the mid-term due to the growing dissemination of UMTS equipment. The number of base

⁹⁰ In German: Nachhaltigkeit in der Informations- und Kommunikationstechnik (NIK)

⁹¹ Stobbe, Lutz (2004): Final report on focus topic mobile communication. Report is available online: <http://www.roadmap-it.de/download/RoadmapMobileKomm.pdf>. (only in German language)

⁹² UMTS Terrestrial Radio Access Network (UTRAN)

⁹³ In the first step we allocated the German data to the population of the EU-5 countries UK, France, Germany, Italy and Spain. Then we assumed that EU-5 represent approximately 70% of EU-25 total (in terms of electricity consumption EU-5 accounted for 67.7% of total EU-25 according to EuroStat). Through that assumption we received respective data for the European Union product stock.

transceiver stations will double until 2010 according to the NIK project. On the other hand, there is a considerable improvement potential regarding the reduction of power consumption. Advanced electronics in conjunction with an optimised thermal management will reduce total energy consumption. But the optimisation of the site infrastructure through more efficient cooling and alternative undisputable power supply shows the best improvement potential.

Table 67: Annual electricity consumption of cellular phone networks (2005)

	Germany Stock 2005 (in units)	Power consumption (in Watts)	Electricity consumption (in TWh/a)	EU-25 Stock 2005 (in units)	Power consumption (in Watts)	Electricity consumption (in TWh/a)
GSM BTS	65.000	2000	1,14	344.870	2.000	5,29
GSM MSC	270	140.000	0,33	1.433	140.000	1,76
UMTS Node	30.000	4500	1,18	169.782	4.500	4,18
UMTS RNC	125	300.000	0,33	663	300.000	1,74
Total			2,98			12,97

Table 68: Calculation of the EU total based on German data

		GSM BTS		GSM MSC		UMTS Node		UMTS RNC	
		stock [units]	consumption [TWh/a]	stock [units]	consumption [TWh/a]	stock [units]	consumption [TWh/a]	stock [units]	consumption [TWh/a]
Germany	82,5	65.000,0	1,0	270,0	0,3	32.000,0	0,8	125,0	0,3
UK	60,0	47.299,5	0,7	196,5	0,2	23.285,9	0,6	91,0	0,2
France	62,4	49.140,2	0,8	204,1	0,3	24.192,1	0,6	94,5	0,2
Spain	43,0	33.908,4	0,5	140,9	0,2	16.693,4	0,4	65,2	0,2
Italy	58,5	46.060,8	0,7	191,3	0,2	22.676,1	0,6	88,6	0,2
Totals	306,4	241.408,8	3,7	1.002,8	1,2	118.847,4	2,9	464,2	1,2
EU-25		344.869,8	5,3	1.432,5	1,8	169.782,0	4,2	663,2	1,7

Table 69: EU 25 estimates for Cellular Phone Network (2005)

Product	Estimated Electricity Use (TWh/a)
Total Cellular phone Network	13.0

■ BAU-Scenario

The business as usual scenario reflects the ongoing modernisation of the mobile phone infrastructure with the shift towards 3rd generation (UMTS). This shift will increase the total number of components such as base transceiver stations (nodes), main switch control, and further links to the backbone telecom network. We assume that the annual energy consumption will increase by factor 1.25 until 2010 and factor 1.75 until 2020.

Table 70: EU 25 BAU Scenario until 2020 for Cellular phone Network

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Cellular phone Network	0,5	25.000	13.0	0,7	24.000	16.3	1,0	23.000	22.8

Electr. = Electricity

■ Eco-Scenario

The Eco-scenario is similarly pragmatic. We assume that the improvements of terminals and infrastructure (e.g. cooling) is in the interest of the carriers (they pay the energy bill). We assume that the annual energy consumption will increase only by factor of 1.15 until 2010 and factor of 1.45 until 2020.

Table 71: EU 25 Eco-scenario until 2020 for Cellular phone Network

	2005 (EU 25 estimates)			2010 (EU 25 estimates)			2020 (EU 25 estimates)		
	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)	Stock (million units)	Electr. use per unit (kWh/a)	Electr. Use (TWh/a)
Cellular phone Network	0,5	25.0	13.0	0,7	21.0	15.0	1,0	19.0	18.9

Electr. = Electricity

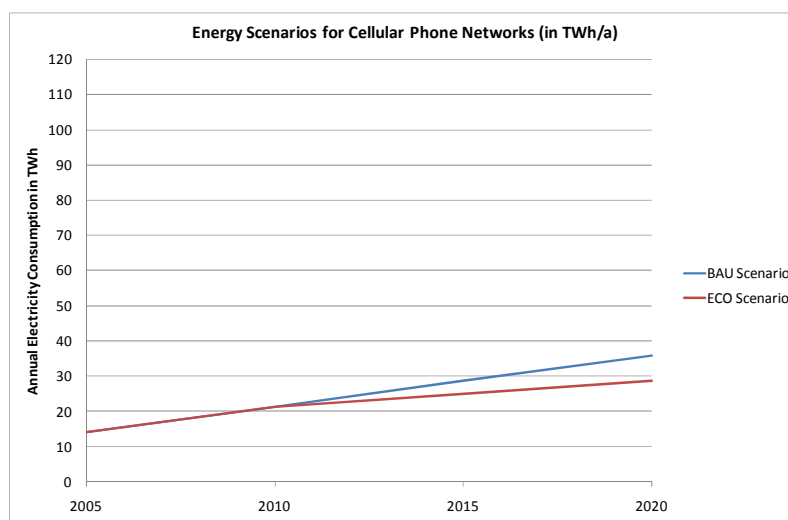
■ Summarising table and conclusions

In conclusion, the cellular phone network is an important contributor to the ICT infrastructure. The energy consumption will increase in the mid-term due to the still growing network. The energy consumption is related to hardware efficiency, traffic volume and the capability create demand scalable network architecture.

Table 72: Estimated improvement potential BAU/Eco-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Product	2005	2020 BAU	2020 ECO	BAU-BAT
Total Cellular phone Network	13.0	22.8	18.9	3.9

Figure 30: BAU and Eco-scenarios for cellular phone networks (electricity use during use phase)



1.3.2.4 Wireless Local Area Networks (WLAN)

No data could be obtained to estimate the electricity footprint of WLAN. More research is needed in this area.

1.3.2.5 Summary

The accumulated annual electricity consumption of the above named ICT infrastructure is approximately **56.4 TWh/a** for the reference year 2005 (see Table 73).

Table 73: Energy consumption of ICT infrastructure in 2005

Infrastructure	Total Energy consumption in 2005 (in TWh/a)	Comments	Data source
Servers	29.1	servers including storage, network components and infrastructure	Consortium E-Server
Telecom network s	14.3	The data could include radio/TV networks	Leading European telecom companies
Cellular phone networks	13.0	GSM and UMTS	NIK (BMBF Germany)
Wireless local area networks	--	No data available	
Radio/TV broadcast equipment	--	No data available – see above on telecom networks	
Total	56.4		

1.3.3. SUMMARY OF EU-TOTALS AND RECOMMENDATIONS

This section summarises the projected development trajectories in terms of stock (in million units) and per unit electricity consumption (in kWh/a per unit), of the ICT devices and of the ICT infrastructures analysed above, both in a business-as-usual (BAU) scenario and in an Eco-scenario where more optimistic assumptions on the improvement of the energy efficiency of the ICT sector (devices and infrastructure) are made.

As already mentioned in section 1.3. , the BAU scenario was built taking into account existing and upcoming policies, existing and upcoming voluntary measures, technical and market trends in the ICT sector:

- the relevant existing policy framework (EuP directive, IPP⁹⁴ policy framework) and likely implementing measures emerging from the existing EuP directive (these implementing measures are likely to require products to meet Energy star / EU Code of Conduct and EU energy label requirements)

⁹⁴ Integrated Product Policy, more info at : <http://ec.europa.eu/environment/ipp/2001developments.htm>

- the relevant voluntary agreements (EU Code of Conduct, Industry self-commitments, etc.), voluntary labelling (Energy star, EU eco label),
- the existing/future trends in technology (existing and emerging future technologies)
- the existing/future market trends

For the Eco-scenario, the improvement scenarios from the existing EuP Preparatory Studies (more ambitious than the likely implementing measures) are also compiled, and other relevant literature data, for products not covered by the EuP studies were integrated.

1.3.3.1 ICT total impact assessment – BAU and Eco-scenarios until 2020

- Complete picture of ICT devices and infrastructure

Table 74 provides the summary of the data presented in section 1.2. and sums the total electricity consumption of the ICT sector for the reference year 2005 and expected evolution until 2020 in both a BAU and Eco-scenarios. As a matter of fact both scenarios indicate a total increase of electricity consumption by factor 1.9 (BAU) and factor 1.3 (ECO) in the mid-term. The comparison of the two scenarios however also shows an improvement potential of over 100 TWh/a until 2020 which highlights the need to encourage the take up and the penetration of energy efficient ICT equipment on the EU 25 market. Table 74 is also depicted in Figure 1 and Figure 2.

Table 74: Estimated improvement potential BAU/Eco-scenario (2020 outlook)

	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Electricity Use (TWh/a)	Difference (TWh/a)
Equipment	2005	2020 BAU	2020 ECO	BAU-BAT
Computers & monitors	42.3	59.0	46	13.0
TV	54	116.4	70.2	46.2
Imaging Equipment	7.8	9.4	6.2	3.2
Mobile devices	0.5	1.2	0.9	0.3
Audio Systems	27.8	18.3	12.4	5.9
VHS/DVD Equipment	4.5	2.3	2.1	0.2
Rough estimate on STB	9.1	26.3	17.3	9.0
Telephones	4.3	6.3	4.2	2.1
Fax machines	1	0.5	0.2	0.3
Modems	4.1	10.4	7.8	2.6
Mobile phones	2.7	4.9	3.3	1.6
Servers and Data centres	29.1	96.0	69.8	26.2
Telecom network	14.3	35.8	28.8	7.0
Cellular phone network	13	22.8	18.9	3.9
WLAN	n/a	n/a	n/a	n/a
EU Totals	214.5	409.7	288.2	121.5

The increase in the stock of ICT appliances, and network infrastructure combined with an extending power on periods of ICT products in a “always on-anywhere and anytime” culture will lead to the **increase of the ICT sector’s total electricity consumption**, although the power demand of new ICT devices will be lower than the average of the ones currently in stock because of the development of more **energy efficient technologies** and of the **miniaturisation of ICT devices which is encouraged by market forces**. Indeed, the existing energy saving potential of new end-user devices – which will reduce the electricity consumption of a single product – is expected to be overcompensated by the amount of products that will enter the market annually.

In parallel, the **demand on servers and data storage capacity is increasing** drastically due to the extended utilisation of ICT end-user devices⁹⁵. Higher data volume and transmission rates, in combination with data safety and secure networks will lead to an increasing demand of ICT infrastructure equipment (e.g. increase in the energy consumption of network server farms, as they need active cooling).

⁹⁵ The increase in the data transfer of short-range networks caused by a potential uptake of “smart objects” will require additional capacities in the long-range networks

Figure 31: BAU-scenario until 2020 – ICT sector total electricity use

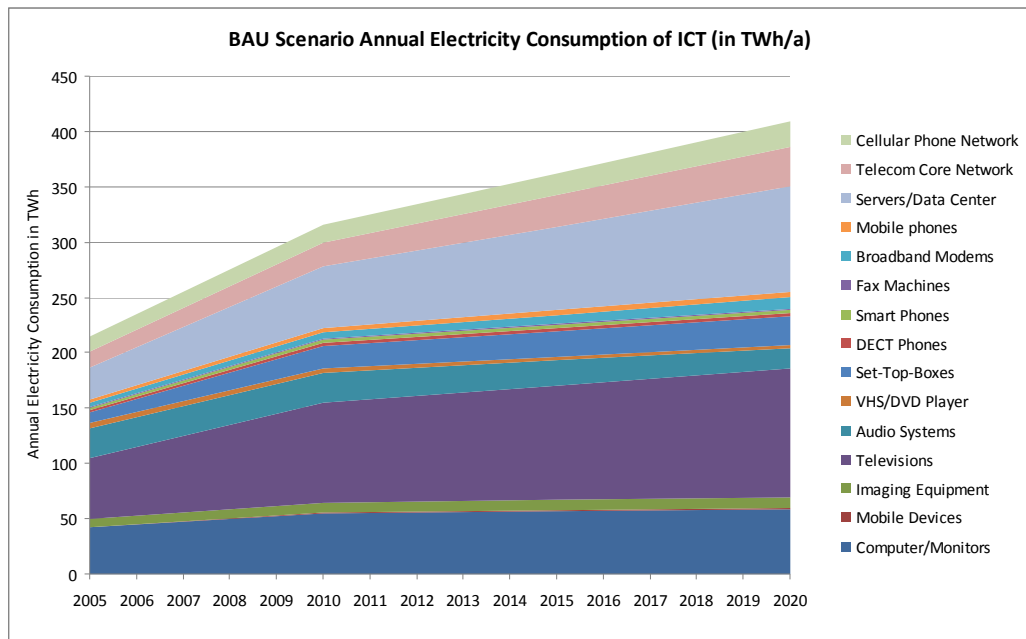
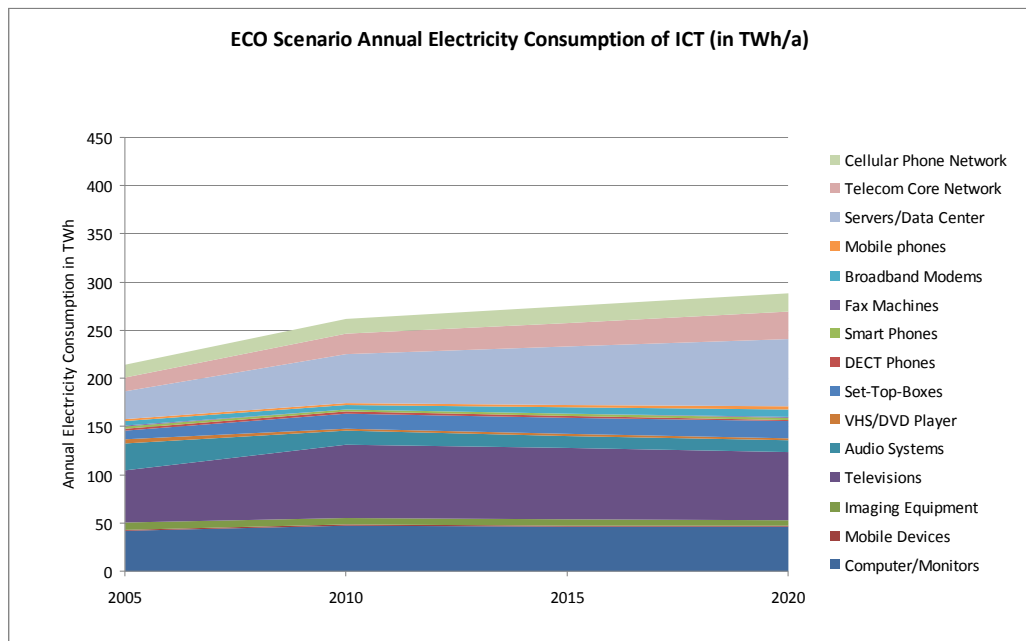


Figure 32: Eco-scenario until 2020 – ICT sector total electricity use



The next paragraphs will identify in more details the general trends driving the future of the electricity consumption of the ICT sector.

- Summary of general trends
- Trends increasing the total electricity consumption:

- **Market growth** (stock increase): due to further dissemination of ICT end-user devices due to increasing options of creating new functionalities and to combine multiple functionalities in a single device, also due to the availability of cheaper ICT devices
- **Development of wired and wireless broadband communication** (Metcalfe's law: which states that the value of a network is proportional to the square of the number of users of the system (n^2)⁹⁶). The technical implications of **wired and wireless broadband communication** are identified at three different levels: 1) Physical layer: optical fibres and coaxial cables, photonic components and waveguide system integration, processor chips (multi core) and memory etc. 2) Data link layer: IEEE 802.3 (Ethernet), IEEE 802.11 (WLAN, Wi-Fi), ATM⁹⁷ etc. 3) Network layer: IPv6⁹⁸, ICMP⁹⁹, OSPF¹⁰⁰
- **Longer standby period** due to more and **more networked and multifunctional products** (increase of always on, networked products)
- **Larger display with higher resolution** (e.g. TVs, PCs, Mobiles)
- **Utilisation of secondary products** (e.g. TVs, PCs, Mobiles)
- **Higher data compressing formats/data encryption for HDTV and secure all-IP network applications** (processing and memory capacity increase)
- Trends reducing the total electricity consumption:
 - **Continuous miniaturisation** of basic hardware elements through intrinsic progress in semiconductor ("More Moore") and micro system technology ("More than Moore" or "Beyond Moore"). Low power is in that respect an essential paradigm.
 - **More mobile devices** using rechargeable batteries and external power supplies are encouraging power management in ICT devices and the development of high efficiency power supplies. (But keep in mind, that rechargeable battery systems are not necessarily more efficient than mains powered devices)
 - **More multifunctional devices** such as imaging equipment, mobile phones/MP3 players, etc. are substituting for multiple single function devices.
 - **Advanced power management:** Scaling of functionality, automatic shift into network standby, maintaining network integrity, power control, etc.

⁹⁶ the idea is that a network is more valuable the more people you can call or write to or the more Web pages you can link to

⁹⁷ Asynchronous Transfer Mode

⁹⁸ Internet Protocol version 6 is a network layer for packet-switched internet.

⁹⁹ Internet Control Message Protocol

¹⁰⁰ Open Shortest Path First protocol is a hierarchical interior gateway protocol.

- **Advanced component and circuitry design:** Power supply unit and inverters, low power network interfaces, dimensioning and control of components such as **processors etc.**
- **Advanced display technologies:** Inorganic and organic LED, bi-stable displays such as e-paper, and field emission displays such as SED all have a high potential to reduce energy consumption. Technical implications of new displays are:
Physical properties: all sizes, thin, flexible, harsh environment, embedded etc.
Functionality: High picture quality, life time, condition sensitive etc.
Economy: Low costs, low power etc.

1.3.3.2 Comparison with other sectors

The accumulated total electricity consumption related to ICT end-user-equipment (158.1 TWh/a) and ICT infrastructure (56.4 TWh/a) amounts to **214.5 TWh/a** for the reference year 2005. This is equivalent to 18.4 Mtoe¹⁰¹ and to 98.3 Mt CO₂ equivalent¹⁰².

In correlation with the overall 2,691 TWh (EuroStat) of electricity consumption in EU-25 this value equals to **8 % share of total**. In correlation with the overall EU 25 CO₂ emissions, the ICT sector represented **1.9 % of the total** in 2005¹⁰³.

As indicated in the discussion of the data, there are still some gaps regarding TV broadcasting infrastructure and regular line telephony. It seems appropriate to correct former assumptions regarding the total energy impact of ICT. If consumer electronics such as TVs (incl. Set-Top-Boxes), mobile devices, audio systems and VHS/DVD players are excluded, the energy consumption of ICT amounts to a total of 118.2 TWh i.e. **a share of 4.3 %**.

In 2020, the BAU scenario shows that the ICT sector could total 409.7 TWh (187 Mt CO₂ equivalent¹⁰⁴) and represent 10.5 % of the total EU 25 electricity consumption (4.2 % of EU 25 CO₂ emissions), vs. 288.2 TWh in an Eco-scenario (132.1 Mt CO₂ equivalent¹⁰⁵) which represents 7.4% of the total EU 25 electricity consumption (3 % of EU 25 CO₂ emissions).

¹⁰¹ 1 toe = 11.63 MWh

¹⁰² For converting the electricity into CO₂ eq. we used the carbon emission factor used by the EuP EcoReport tool which the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh).

¹⁰³ EU 25 CO₂ in 2005 = 4923.3 MtCO₂ (source : European Environmental Agency, Annual European Community greenhouse gas inventory 1990 - 2006 and inventory report 2008)

¹⁰⁴ For converting the electricity into CO₂ eq. we used the carbon emission factor used by the EuP EcoReport tool which the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh).

¹⁰⁵ For converting the electricity into CO₂ eq. we used the carbon emission factor used by the EuP EcoReport tool which the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh).

In a BAU scenario the share of the total electricity represented by the households and services sector will increase from 57% in 2005 to 62% in 2020, and ICT devices could play an important role in this increase (proliferation of ICT devices) but also ICTs could enable electricity savings e.g. in the building sector as it will be further analysed in later task 2. The industry sector will represent a reduced share of EU 25 total electricity consumption in 2020 (36%) compared to 2005 (40%) and ICTs could also act as an enabler for energy savings in this sector (see later task 2 and 3) (see Figure 6).

Because this study should cover the situation in EU 27, an estimation of the influence of two newest members Romania and Bulgaria on the share of installed ICT in the EU-27 was done. Based on market data from EITO¹⁰⁶, it was estimated Romania and Bulgaria represent about 0.7% of the EU 27 market.

This share was calculated based on estimates of the EU 27 market (assuming Malta and Cyprus are negligible), Romania represents about 0.5 % of the ICT market (in million EUROS) and Bulgaria represents about 0.2 % of the whole EU 27 ICT market in 2005.

These markets are assumed to grow faster compared to the situation in older member states¹⁰⁷, and could reach 1.4% (double) in 2010 compared to 2005.

In 2020, assuming ICT penetration in Bulgaria and Romania will catch up with that of older member states; the extrapolation was based on projections of population data, leading to estimating that Romania and Bulgaria could represent 5.4 % of the EU 27 market in 2020.

Considering these assumptions, and making the rough assumption that the share of the ICT market is proportional to the share of the ICT energy use (i.e. if one country represents 5% of the EU 27 total ICT annual market in million Euros, than it represents about 5% of the EU 27 total ICT sector energy consumption in TWh/a), then we can calculate the following estimates for EU 27, which are not very different from the EU 25 results in terms of the share of electricity use represented by the ICT sector (see Table 1):

¹⁰⁶ EITO 2007 Report Table 16

¹⁰⁷ EITO 2007 Report table 16 states that the market will grow of 2.9% for EU 27 (excluding Malta, Cyprus, Bulgaria) compared to 9.3% for the ICT market in Romania (in million Euros)

Table 75: EU estimates of the ICT sector electricity use

	2005	2020 BAU	2020 ECO
Total ICT sector electricity use in EU 25 (TWh/a)	214.5	409.7	288.2
ICT sector without consumer electronics in EU-25 (TWh/a)	118.2	245.1	185.2
Total ICT sector electricity use in EU 27 (TWh/a)	216.0	433.1	304.7
ICT sector without consumer electronics in EU-27 (TWh/a)	119.4	259.1	195.8
Share of the ICT sector electricity use over total EU 27 electricity use (%)	7.8%	10.9%	7.7%
Share of the ICT sector electricity use (without consumer electronics) over total EU 27 electricity use (%)	4.3%	6.5%	4.9%

Table 76 provides the same data expressed in CO₂ equivalent emissions from electricity use. The study finds that in 2005, the ICT sector represented 98.3 Mt CO₂ equivalent¹⁰⁸ (i.e. 1.9 % of the total CO₂ emissions of the EU-25 in 2005¹⁰⁹). In a BAU scenario, this amount is estimated to reach 187.7 Mt CO₂ equivalent⁶ (i.e. 4.2 % of EU-25 CO₂ projected emissions) for the year 2020 and 132.1 Mt CO₂ equivalent⁶ in an Eco-scenario (i.e. about 3 % of the EU-25 CO₂ projected emissions). However, it should be noted that the various assumptions used for the calculation of the equivalent CO₂ emissions lead to an **overestimation of the CO₂ emissions related to the ICT sector in 2020**: indeed, while assessing the environmental footprint of the ICT sector, business lead initiatives to encourage the use of renewable energy to power ICT industries were not taken into account. In particular and more importantly, the emission factor used to convert electricity consumption into equivalent CO₂ emissions was assumed to remain constant throughout the period under review (2005-2020). However, with the foreseen integration of a higher share of renewables in the European energy grid, this emission factor will probably decrease, leading to an overestimation of the ICT footprint in terms of CO₂ equivalent emissions. Nevertheless the estimations calculated still provide a good order of magnitude.

¹⁰⁸ For converting the electricity into CO₂ eq. we used the carbon emission factor used by the EuP EcoReport tool which the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh).

¹⁰⁹ EU 25 CO₂ in 2005 = 4923.3 MtCO₂ (source : European Environmental Agency, Annual European Community greenhouse gas inventory 1990 - 2006 and inventory report 2008)

Table 76: EU estimates of the ICT sector electricity use converted in CO₂ equivalent¹¹⁰

	2005	2020 BAU	2020 ECO
Total ICT sector CO ₂ equivalent emissions from electricity use in EU 25 (Mt CO ₂ eq.)	98.3	187.7	132.1
ICT sector CO ₂ equivalent emissions from electricity use without consumer electronics in EU-25 (Mt CO ₂ eq.)	54.3	112.3	84.9
Total ICT sector CO ₂ equivalent emissions from electricity use in EU 27 (Mt CO ₂ eq.)	99.0	198.5	139.6
ICT sector CO ₂ equivalent emissions from electricity use without consumer electronics in EU-27 (Mt CO ₂ Eq.)	54.7	118.7	89.7
Share of the ICT sector CO ₂ equivalent emissions from electricity use over total EU 27 CO ₂ emissions (%)	1.9%	4.5%	3.1%
Share of the ICT sector CO ₂ equivalent emissions from electricity use (without consumer electronics) over total EU 27 CO ₂ emissions (%)	1.1%	2.66%	2.0%

1.3.3.3 Interpretation of BAU- and Eco-scenario

The analysis of the trends and driving factors of the total electricity consumption of the ICT sector enables to identify the **key ICT equipment for which significant improvement potential is available and the key parameters that will affect electricity consumption in coming years**: i.e. key technical issues to overcome in order to slow down the trends towards increased electricity consumption of the ICT sector and speed up the trends towards a reduced electricity consumption of the ICT sector.

The following paragraphs lists the ICT equipment where significant improvement potential was identified and summarise the **main technical issues in the ICT sector**, based on the different analysis made at product and infrastructure level.

In order to overcome these issues, voluntary actions such as Energy Star, EU Energy labelling but also legislation (EuP Directive future implementing measures) and industry initiatives are in constant development and already exist and will be identified. These, and further recommendation will also be discussed later (see section 1.3.3.4) to speed up the market penetration of efficient ICT devices and to reduce the overall electricity consumption of the ICT sector.

¹¹⁰ For converting the electricity into CO₂ eq. we used the carbon emission factor used by the EuP EcoReport tool which the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh).

- Key ICT equipment

Table 74 enables to identify the ICT equipment **with the highest improvement potential** (i.e. higher than 5 TWh/a savings): **TVs, servers and data centres, computers and monitors, set-top boxes, and telecom core networks**. These ICT equipments are also estimated to represent over 80 % of the total electricity consumption of the ICT sector in a BAU scenario in 2020.

- Technical issues

- Power supplies and power management systems

ICT devices powered through an external power supply and rechargeable batteries (e.g. mobile phones, laptops) will become more ubiquitous. Therefore, the energy efficiency of power supplies and power management systems in these ICT devices are important factors to consider in the future. **The comparatively low battery efficiency** is the main obstacle. Indeed the miniaturisation of mobile devices is limited by energy requirements and unlike the semiconductor technology, where Moore's Law has led to significant miniaturisation, the energy capacity of batteries has increased by just 20% in the last 20 years.

Energetically more efficient power supply technologies such as low temperature fuel cells are expected to enter the market in the coming years, reducing the electricity demand per unit ICT device. Development objectives for the battery industry include an increase in power density by a factor of 3-5 and the reduction of self-discharge. With chip-controlled 'intelligent batteries', battery life can be extended and the remaining capacity can be determined more precisely. Great progress has been made with lithium-polymer batteries in particular. Since conventional batteries have inherent limitations, the **development of alternative energy sources** (e.g. photovoltaic, piezo-elements, and body energy) and the minimisation of the energy consumption of ICT devices are already in the pipeline. It is expected that in a few years mobile telephones will be able to cover their energy requirements with solar cells¹¹¹.

Nevertheless, it is necessary to understand that mains powered devices could be designed more energy efficient than mobile devices because losses through the battery charging and energy storage is avoided by direct (mains) power supply.

Research activities to support innovation in these fields should be encouraged.

- Standby issue

Always-on devices in particular and devices in standby mode will become more common in the future (pervasive computing vision) and could cause a significant

¹¹¹ Reichl, H. (2000): Visions for Mobile Electronics. In Electronics Goes Green 2000+, Volume 2, page 91ff, VDE-Verlag Berlin, Offenbach 2000

increase of the total electricity demand. The recent EuP Preparatory Studies on the standby function indicated a possible improvement potential:

- Televisions and other consumer electronics achieved passive standby of 0.2 Watts thanks to specifically designed low power controller ICs and advanced switched power supply units with a conversion efficiency of more than 90%

This issue will become more relevant due to more and **more networked and multifunctional products** (increase of always on, networked products) and is a horizontal issue cross cutting several categories of products (i.e. set-top boxes where the active standby mode requires almost as much power as the on mode, TVs, monitors, laptops, audio systems, etc.).

- Improvements in the semiconductor industry and miniaturisation of devices

The incremental improvement of energy efficiency on component, system, and product level is generally driven by the **miniaturisation of electronics** and the **progress in semiconductor technology**.

In the past forty years there existed one single technology driver for the whole electronics industry. It is the technological progress in semiconductor-based Integrated Circuit (IC) and monolithic Large Scale Integration (LSI). The semiconductor industry follows the paradigm of the so called Moore's Law. It implies a continuous acceleration in computing and cost performance for semiconductor ICs over a given time. In the relentless pursuit of Moore's Law – as a kind of self-fulfilling prophecy – the electronics industry showed impressive technical success in miniaturization, and expanded product applications and related product consumption patterns. And although experts are of different opinions on whether Moore's Law approaches its physical and economic limits, over the next ten to fifteen years, technological progress in semiconductor performance and other enabling technologies will remain vibrant.

Recently, the driving force of a monolithic integration or "System on a chip" (SoC) has been influenced by a hetero-system integration approach in a sense of a "System in Package" (SiP). This new approach provides a wider spectrum of functionalities and the option for the combination of functionalities such as Micro Electro Mechanical Systems (MEMS). With such technological progress not only new product applications are possible, the technical options for improving the energy efficiency of electronic systems is increasing as well.

These technical issues are the main barriers identified for improving the energy efficient of the ICT sector. However, best available products and business initiatives already on the EU market shows that they can be overcome and could set targets for further improvement of the European ICT sector.

Best available products

With current speed of technological progress it is possible to achieve low power consumption on component and system levels. The recent EuP Preparatory Studies indicated this potential:

- Low power printed circuit boards based on thinner substrates and embedded device technologies.
- Advanced thermal management with integrated heat sinks, liquid cooling, and active power management.
- Advanced non-volatile memory or storage technologies which enables to shut off-power without losing content or saving to hard drives or disks. NVM includes Erasable Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), Flash memory, non-volatile random access memory (NV-RAM) such as Ferroelectric RAM (FeRAM) or Magneto-resistive RAM (MRAM).
- Advanced display technologies such as Liquid Crystal Display (LCD) with areal dimming LED backlight systems, Organic Light Emitting Diode (OLED) display or field Emission Displays (FED).
- Power management of always-on networks through the application of the next generation Internet Protocol Version 6 (IPv6)

Business led initiatives

A distinction is made between business initiatives to improve energy efficiency, and other initiatives aiming at making the ICT sector becoming carbon neutral through compensation actions such as investments in the renewable energy sector. These latter initiatives have become more and more popular and have been put forward by leading companies such as Google, who announced it would become carbon neutral by the end of 2008, one of Google's strategies being to increase its share of renewable energy use. Also recently (2007) Toshiba¹¹² and Dell¹¹³ have set "plant a tree" programs offering the possibility to their customers to offset the carbon emissions of a number of devices including laser printers, desktops, workstations, and servers by planting a tree each time a device is purchased. Here, we focus on business led initiatives to improve energy efficiency of the ICT sector in terms of end-user device energy use (during use phase) and in terms of infrastructure. In the last decade impressive improvements have already been observed. For example, mobiles phones are now 100 times more efficient

¹¹² Toshiba « Carbon Zero » Scheme

http://uk.computers.toshiba-europe.com/cgi-bin/ToshibaCSG/generic_content.jsp?service=UK&ID=carbonneutral

¹¹³ « "Plant a Tree for Me" initiative » in partnership with the carbonfund organisation
<http://carbonfund.org/>

than in 1990¹¹⁴. Also, as a result of the EICTA's self-commitment on TVs standby power established in 1996, over the past decade the sales-weighted standby power average for the TVs of the companies participating has decreased from more than 6 watts to almost 1.8 watts. Furthermore, continuous innovation in flat screen TV technology has resulted in TVs that consume less than their equivalent "tube" TV-brethren before, and this energy efficiency will continue to improve in the future.

These technical options, best available technologies and business lead initiatives, exemplify the improvement potential of the electronics industry. Whereas the industry should exploit the already existing improvement potential – low hanging fruits – it is necessary to **focus research and development on the investigation of completely new concepts and technologies** for reducing the energy consumption.

- Existing framework to overcome these issues

The **existing and developing frameworks such as the EuP directive** (including future implementing measures on standby power requirements and external power supplies, etc.), **the IPP policy framework should be capable of addressing the technical issues mentioned above and support the implementation of necessary implementing measures if any**. However, there is also the need to further encourage the penetration of best available technologies and "green" business initiatives.

The existing **Energy star and Eco-labelling scheme** will help private and public consumers to select the most energy efficient products, and the existing European relevant technology platforms will help to boost innovation in the ICT sector.

However the **take up of energy efficient products should still be further encouraged** as well as **innovation** to speed up the move towards more efficient products on the European market.

1.3.3.4 Possible Recommendations

There is a risk that inefficient energy schemes will prevail, as no strong incentives for energy-efficient design are given in the international economy.

- Recommendations – Uptake of energy efficient ICT equipment
- Setting Standards

Setting standards on the energy consumption of ICT equipment could prevent poor efficiency products from being on the market and push companies to manufacture energy-efficient ICT equipment

- Public procurement and Integrated Product Policy

¹¹⁴ Intellect. *High tech Low Carbon*. 2008

A European green public procurement scheme should be adopted. This scheme would enable a significant amount of European public procurement to be dedicated to energy-efficient, and innovative products and services, e.g. by setting mandatory targets on the energy efficiency of purchased ICT devices. This scheme should take into account the importance of underpinning research and development in the ICT domain while considering also small and medium size enterprises. The capability to specify and purchase these innovative products requires “intelligent customers” and a shared vision with the suppliers. In the procurement of ICT energy efficiency issues, useful life, waste disposal characteristics and ergonomics should be considered. It will be a major challenge to develop a long-term procurement policy despite short innovation cycles of ICT products.

- Energy labels for ICT

More and more companies in various business sectors have been starting to understand that “green communication” can improve their corporate image. Thereby, eco-friendly products or environmental initiatives are highlighted by manufacturers.

The European energy label, which is already in use for some domestic appliances under the European regulation on energy, should also be introduced for ICT devices that are operated on the mains supply (plug-in and permanently installed devices) to **complete the Energy star label which is currently only available for office equipment.**

The focus for this measure is the expected continuous operation of a large number of devices per household or workplace, which may also lead to important energy consumption in the case of small or medium-sized power requirements. Continuous operation (implying standby issues) can be expected for all devices forming part of the network infrastructure (such as modems, hubs, gateways, base stations, etc.) and for all servers.

For mobile ICT devices that are charged by a power supply unit, a label for power supply units is possible.

Associations of industry at EU level such as EICTA supports Energy star voluntary program for more efficient devices as this voluntary scheme provides the advantage of being flexible and rapidly adaptable which is an advantage in a fast moving sector such as the ICT sector.

- Financial incentives to foster “green products”

For instance, in Denmark financial incentives were created to increase the purchase of efficient fridges and freezers. Indeed, in 1995, just one-quarter of the fridges and freezers sold in Denmark had “A” or “B” ratings. To spur sales of the most energy-efficient models, Denmark created the Electricity Savings Trust, a temporary subsidy program that gave consumers who chose A-rated appliances a \$100 rebate at the time of sale. The rebates persuaded retailers to devote more resources to marketing and to stocking a variety of efficient models. By 2005, after the Trust had

distributed \$20 million in three rounds of rebates, 92% of the refrigerators and freezers sold in Denmark had “A” ratings.

In various Member States, bills reducing or nullifying VAT of “green products” have been launched or suggested. The principle is that customers do not have to be reluctant because of the price of these eco-friendly appliances.

- Promote value efficiency and Life Cycle Cost (LCC) over purchase cost

It is generally recognised that energy efficiency is not a main criterion influencing the ICT procurement decisions. This fact is partly due to the lack of information on potential benefits for customer in choosing energy-efficient products. Indeed, most customers only take into account the purchase cost, and do not realise that they will pay energy to use their appliances. Thus, the life cycle cost, which adds purchase, use and potential end-of-life costs, is the only relevant figure.

Indeed, product A can have a higher purchase cost than product B, but as it is more efficient, its use cost will be lower. Thereby, the LCC of product A may be lower than the LCC of product. This data is not in customer’s mind, and he is not aware that it could be more profitable to buy an appliance with a higher purchase cost.

Actions to effectively promote the use of LCC over purchase cost include making it mandatory for public purchasers to consider LCC instead of price when buying energy-using products (in link with the European Green Public Procurement scheme mentioned above). Another idea is to mention the LCC of a product (calculated according to a defined standard) on the Energy label.

- Recommendations to encourage innovation (R&D)
 - The R&D in ICT is already well structured around the European Platforms already mentioned (ENIAC, NESSI, ARTEMIS, Etc.) and strategic research agenda already mentions research projects to overcome the technical issues presented in section 1.3.3.3. Further research activities should be encouraged in the different technology areas mentioned above: WLAN (to provide statistical data on installed infrastructure and energy consumption), Telecom network (to provide data on the evolution of the network), power supplies and power management systems, standby issue (research already started within the framework of the EuP preparatory study on Lot 6) as well as in the semiconductor industry. The following measures could be taken to enhance innovation in the ICT sector.
 - Tax credit

Ensure that innovation in R&D is rewarded through appropriate means such as tax credit schemes for R&D and support for technology clusters as global poles of competitiveness.

- Support the semiconductor industry

The semiconductor industry is a key industry in Europe for the entire ICT innovation cycle, with a major enabling role and specific R&D, manufacturing situation. Specific measures are needed to secure a global level playing field with other industrialised regions in the world, to ensure stronger support for manufacturing and strengthen ICT clustering potentials. This vision is also shared by the EU DG TREN ICT task force¹¹⁵.

Table 77 summarises the different necessary actions to reach the Eco-scenario developed in this study.

Table 77: Summary of recommendations for DG INFSO

Equipment	Equipment-specific recommendations to reach the Eco-scenario	General recommendations to reach the Eco-scenario
Computers and monitors	<ul style="list-style-type: none"> - set minimum requirements for power consumption in all modes (on, standby, etc.) - have the power management mandatory enabled - set efficiency requirements on the power supply 	<ul style="list-style-type: none"> - Support Innovation, R&D - Information to consumer to promote value efficiency and life cycle cost over purchase cost - Adopt a European green public procurement scheme - Extend the Energy Star program or the Energy label to other ICT products (with priority to the most significant in terms of overall energy consumption: e.g. for TVs) - Set financial incentives to foster green products - Tax credit: ensure that innovation in R&D is rewarded - Support the semiconductor industry
TVs	<ul style="list-style-type: none"> - Extend the scope of the Energy Label to TVs 	
Mobiles devices	<ul style="list-style-type: none"> - More information to end-user in order to avoid no-load losses (when charger is connected to the mains but no device is being charged) 	
Audio systems	<ul style="list-style-type: none"> - see general recommendations 	
VHS/DVD	<ul style="list-style-type: none"> - see general recommendations 	
Set-top boxes	<ul style="list-style-type: none"> - see general recommendations 	
Telephones	<ul style="list-style-type: none"> - see general recommendations 	
Fax	<ul style="list-style-type: none"> - Set minimum requirements for power consumption in standby mode (network standby) 	
Modem	<ul style="list-style-type: none"> - see general recommendations 	
Mobile phones	<ul style="list-style-type: none"> - More information to end-user in order to avoid no-load losses (when charger is connected to the mains but no device is being charged) 	
Servers and data centres	<ul style="list-style-type: none"> - Support the development of the European Code of Conduct for Servers and data centres: energy performance measures are necessary to establish eligibility for utility rebates or tax incentives, or to create procurement requirements 	
Telecom core	<ul style="list-style-type: none"> - Further research is needed to assess the evolution of the telecom core network 	
Mobile network	<ul style="list-style-type: none"> - see general recommendations 	

¹¹⁵ Fostering the Competitiveness of Europe's ICT Industry, EU ICT Task Force Report, November 2006, online available at:

http://www.eeca.eu/data/File/ESIA%20Publications/icttf_report_exe_theme_paper.pdf

1.4. ASSESSMENT OF ENVIRONMENTAL EFFECTS AND SOCIAL IMPACTS

1.4.1. ASSESSMENT OF ENVIRONMENTAL EFFECTS

This section complements the analysis of the ICT sector's environmental footprint by discussing the environmental impacts of the end-of-life phase and production phases of ICT equipment.

1.4.1.1 End-of-life phase

■ ICT waste production 2005-2020 – Trends and driving factors

As seen in section 0, in spite of gains in energy efficiency per unit product manufactured, rapid market growth results in increasing material turnover. Also, fast innovation in the ICT sector¹¹⁶ leads to a decrease of the average life time of products which aggravates the waste issue and translates into growing amounts of waste. However, miniaturisation of ICT products account for less waste. In summary, identified driving factors defining the trends in ICT waste production are:

- increased ICT penetration on the EU market (growth of the installed stock of ICT devices and infrastructure)
- shifts in technologies: e.g. shift from CRT monitors (including cathode ray tubes and lead) to LCD monitors
- shift from stationary to mobile applications (e.g. PC to laptops)
- decrease in average useful life of ICT devices (halving the lifetime of ICT devices implies a long term doubling in ICT waste)
- growing trend towards “pervasive computing” and the use of embedded ICT in everyday use object which could lead to new e-waste streams¹¹⁷. Indeed, embedding ICTs into clothing, furniture, and white goods might reduce their usage time and modify their waste characteristics so that the amounts of waste will grow and become less recyclable. However, the extent to which these non-ICT objects will be

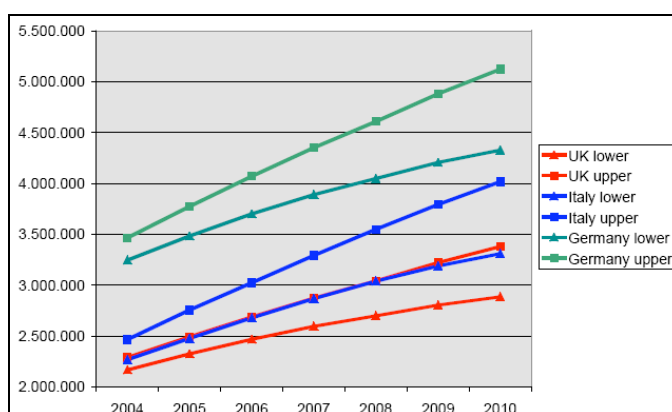
¹¹⁶ According to Moore's Law, the performance of ICT products doubles every 18 months. This observation has shown to be true not only for the processor speed but also for the memory capacity and data transmission speed (Hilty and Ruddy in <http://www.unige.ch/iued/wsis/DOC/207EN.PDF>)

¹¹⁷ These non ICT objects (“smart objects”) are out of the scope of the present task 1 when calculating the impacts of ICT use. The reason is that in the future, it is hard to imagine that these devices will require batteries to be charged frequently, or that they will be connected to a main. Therefore, it is more plausible to assume that their energy consumption will be negligible and/or that they will be powered by decentralised energy sources (photovoltaic, thermo-elements, mechanical energy conversion, etc.) (source: Hilty and al. *The future impact of ICT on environmental sustainability. Fourth Interim Report. Refinement and quantification*. Institute for Prospective Technological Studies (IPTS)). However, in later tasks the energy consumption of such non-traditional ICT devices will be assessed whenever possible.

bought and their penetration on the EU market cannot be determined in a robust way.

In 2001, the European **electronic waste** (WEEE, including ICTs) accounted for about **4 % of the municipal waste**, with in 2000 a share of 90 % of the WEEE being either incinerated, land filled or recovered without special treatment¹¹⁸. The EU estimates that the amount of **WEEE will increase at a growing rate of 3-5%** in the years to come, leading to a doubling period of 12 years (growth rate about three times higher than the average growth of municipal waste). ICT equipment is just a part of it. Estimations on the number of computers thrown away in UK, Germany, Italy, and, Bulgaria show the increased penetration of computers in the market and the trend towards a reduction of their life time leads to a **much higher rise of the number of PCs in the waste stream** (Figure 33).

Figure 33: Number of computers that will be thrown away in Germany, Italy and UK (upper and lower estimated in units)¹¹⁹



In Germany, for the year 2003, out of the 2 million tonnes of electronic waste, ICTs accounted for 753,000 tonnes¹²⁰. The same share applied to EU results in a total share of **1.5 % of ICT waste of total solid municipal waste**. Assuming this share stayed the same until 2005, this estimate leads to about 8 kg of ICT waste per person in EU 25 for the year 2005, thus a total of about **3.6 million tonnes of ICT waste in EU 25 for the reference year 2005**¹²¹.

¹¹⁸ European Union 2000

¹¹⁹ E-living : Life in a Digital Europe FP5 project <http://www.eurescom.de/e-living/deliverables/e-liv-D14-Ch3-Environment.pdf>

¹²⁰ Lorenz Erdmann, Siegfried Behrendt. *The future impact of ICT on environmental sustainability. Second Interim Report. Script.* Institute for Prospective Technological Studies (IPTS)

¹²¹ Calculation based on EUROSTAT data on solid municipal waste in EU 25 for the year 2005 (519 kg/person/year) and on EUROSTAT data on total EU 25 population of 461,603,958 inhabitants, and assuming that ICT waste represents 1.5 % of total municipal waste.

According to a previous European study¹²², **a doubling of ICT waste until 2020 seems to be a realistic magnitude**. This would lead to average **15 kg of ICT waste per year per person in EU 25**, and a total of **7.2 million tonnes of ICT waste in 2020**. However, this assessment is **highly uncertain**.

In a socio-economic simulation study conducted for the European Commission¹²³, with a time horizon running up to 2020, an analysis was carried out for three different policy scenarios. Even in the scenario which assumed that environmental regulation would be put into force to internalise external costs (e.g., accounting for the externalities of extracting and processing raw materials, supplying energy, and disposing of waste), the total EU-15 WEEE mass flow increased by a factor of 2.7 (compared to the level of 2000) in the best case and by 4.0 in the worst case. In the two scenarios without additional environmental regulation, the WEEE flow increased by a factor of 3.1–7.0 (again compared to the level of 2000).

Furthermore, taking IBM's¹²⁴ technological vision literally, it could be expected that at a 2010-2015 horizon, about 1000 million people will use more than 1,000,000 million networked objects around the world. This corresponds to about "1000 smart objects per person in the rich part of the world"¹²⁵. Assuming an average weight of 10g of electronic components (microprocessors, communication module) per object, the weight of new ICT products, e.g. embedded type products or smart products would amount to **10 kg/year per person in 2010-2015** which adds to the previous estimate of "traditional ICT waste".

The uncertainty over ICT waste is due to limited knowledge about how far some types of ICT devices will dematerialise, miniaturise, and about the future average useful life of ICT devices. According to a European study¹²⁶, the future contribution of ICT waste to non recycled solid municipal waste (i.e. non-recycled municipal solid waste is the residual fraction burnt in incinerators or placed in landfill) will range **between 4% and 26% in 2020**, depending mainly on the future diffusion rate of ICTs, their future useful life expectancy, the recycling of ICT waste, and the assumed level of dematerialisation (i.e. material intensity influenced by product-to-service shift, and by the material efficiency of production processes). This would lead to **ICT waste production per**

¹²² Behrendt, Erdmann. *The future impact of ICT on environmental sustainability. Second Interim Report. Script*. Institute for Prospective Technological Studies (IPTS) 2003

¹²³ Hilty and al. *The future impact of ICT on environmental sustainability. Fourth Interim Report. Refinement and quantification*. Institute for Prospective Technological Studies (IPTS) 2004

¹²⁴ « A billion people interacting with a million e-businesses with a trillion intelligent devices interconnected » IBM Chairman Lou Gerstner

¹²⁵ Hilty. *E-waste – an emerging risk ?* Environmental Impact Assessment Review Volume 25, Issue 5, July 2005, Pages 431-435 Environmental and Social Impacts of Electronic Waste Recycling. 2005

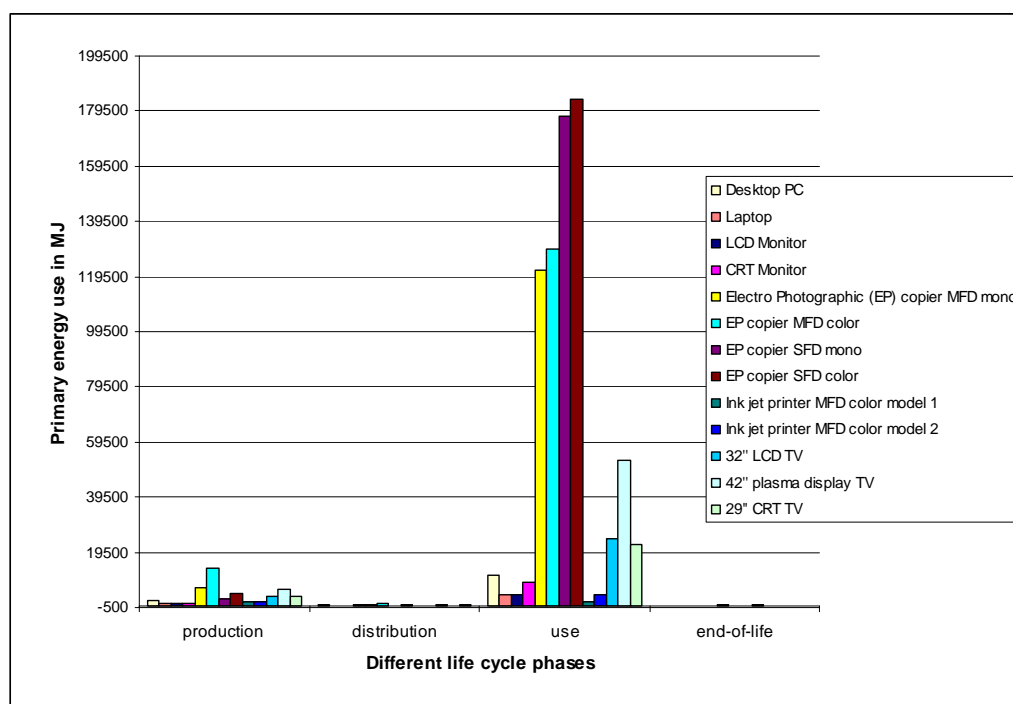
¹²⁶ *Future impacts of ICT on sustainability*. IPTS final report <http://ftp.jrc.es/eur21384en.pdf>

person of between 8kg and 110 kg/year, and a total amount of ICT waste between 3.6 and 51 million tonnes of ICT waste in EU 25 for the year 2020¹²⁷.

The main challenges related to the end-of-life of ICT equipment rely in the avoidance of **toxic substances** (e.g. lead, copper, mercury, cadmium, also flame retardants and plastic softeners), the **reduction of generated waste through better recycling** (a major part of e-waste in general over 50% consists of recyclable material such as aluminium, ferrous metals, copper, or glass¹²⁸), the **recovery** of valuable materials (e.g. gold), **and the optimization of the life and use of the ICT end-user devices** (e.g. though sharing and leasing).

In terms of primary energy used during the end-of-life phase expressed in mega joules, the EuP lot 3, 4 and 5 studies provide insights on the relative significance of the end-of-life phase compared to the production, distribution and use phase. Results show that the end-of-life phase is negligible in terms of primary energy consumption (Figure 34).

Figure 34: Primary energy use in different life cycle phases of ICT devices (EuP studies)¹²⁹



¹²⁷ Calculation based on a projected EU 25 population of 468,682,000 inhabitants and assuming the future non-recycled municipal solid waste could increase by 33% on worst case or decrease by 40 % under best case assumptions (assumptions taken from IPTS study mentioned in note **Erreur ! Signet non défini.**). The fraction of non recycled solid municipal waste could be very different depending on the future technical, economic, legal and behavioural conditions for recycling.

¹²⁸ Hilty and al. *The future impact of ICT on environmental sustainability. Fourth Interim Report. Refinement and quantification.* Institute for Prospective Technological Studies (IPTS) 2004

¹²⁹ Figure based on data from EuP studies lot 3, 4, and 5

- Related existing and future policy frameworks, and voluntary initiatives

The EU WEEE directive¹³⁰ (Directive on Waste Electric and Electronic Equipment) addresses the issue of the end-of-life stage of ICTs, targeting the challenge represented by the growing fraction of ICTs in municipal solid waste, by setting –among others– recycling and recovery targets. The RoHS directive (Restriction of Hazardous Substances) is driving companies to use less toxic materials in their products.

However, some of the requirements in these regulations are not so easy to implement for industries. Indeed, some of the requirements developed in these regulations could be related to the restriction of materials having either expensive or difficult to manage substitutes, and it is unclear how these changes will impact the industry in the long term as for substitutes¹³¹, the industry has little risk assessment data on their impact to human health. This situation should however in principle be avoided by the existence of the exemptions mechanism of the RoHS Directive, which exempts certain products from the provisions of the Directive, if the substitutes happen to be not available for an economic or a technical reason.

¹³⁰ http://ec.europa.eu/environment/waste/weee/index_en.htm

¹³¹ Schoenung et al. *Adopting lead-free electronics : Policy differences and knowledge gaps*. Journal of industrial ecology 8 (4). 2005

Table 78: EU 25 policy framework/voluntary measures related to ICT waste management¹³²

Related environmental EU goals and targets	<ul style="list-style-type: none"> ○ General goal relevant for waste generation are: <ul style="list-style-type: none"> - consumption of renewable and non-renewable resources should not exceed carrying capacity, and; - achieving a decoupling of resource use from economic growth, through significantly improving resource efficiency, dematerialisation of the economy and waste prevention. ○ More specific goals are to: <ul style="list-style-type: none"> - reduce the quantity of waste going to 'final disposal' by 20% from 2000 to 2010, and by 50% by 2050, with special emphasis on cutting hazardous waste ○ Targets for WEEE are to by the end of 2006: <ul style="list-style-type: none"> - recycle between 50% to 80%, depending on the type of equipment, - recover at least 75% of ICT equipment and waste containing a cathode ray tube. ○ Targets for RoHS from 1 July 2006: <ul style="list-style-type: none"> - new EEE put on the market must not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE).
Relevant existing and upcoming EU policy initiatives	<ul style="list-style-type: none"> ○ IPP communication ○ WEEE directive ○ RoHS directive ○ EuP directive ○ EMAS ○ Directive 1999/31/EC on the landfill of waste (Landfill Directive) ○ 6th EAP <ul style="list-style-type: none"> - 6th EAP's thematic strategy on resources and waste ○ Communication COM(2003) 301 final. Towards a thematic strategy on the prevention and recycling of waste. (Communication on thematic strategy on resources and waste)

The EU recognised the limitations of the WEEE/RoHS legislation in terms of prevention and the need to influence product design in a more holistic manner in order to deliver significant environmental improvements to future products. It is estimated that over 80% of all product related environmental impacts are determined during the product design phase¹³³. Integrating environmental considerations as early as possible into product development (through Eco-design) is therefore the most effective way of introducing changes and improvements to products. The EuP directive addresses this issue, targeting to reduce the environmental impacts of EuPs during their entire life cycle (life cycle thinking approach), including during the production phase.

The industry is also taking initiatives to reduce the environmental impacts of the end-of-life of ICT equipment. Two of the world's most prominent technology **companies have launched new programs to help facilitate the reuse and recycling of old electronic devices**. Microsoft has announced an expansion of its worldwide Microsoft

¹³² Arnflak. *The future impact of ICT on environmental sustainability. Fifth Interim Report. Evaluation and Recommendation*. Institute for Prospective Technological Studies (IPTS) 2004

¹³³ GFEA, 2000

Authorized Refurbisher (MAR¹³⁴) program that accepts old equipment from companies that need to dispose of it. In the USA, Sony has launched a “take back recycling program” to increase e-waste recycling in general, and computer recycling in particular.

Finally, it should also be noted that through enabling e-commerce which induces packaging waste (see later tasks on dematerialisation), and through the potential of improving waste management processes, and enabling virtualisation of goods (see later tasks), ICTs influence the amount of solid municipal waste. Waste management process is one of the key priorities of the Sixth Environmental Action Programme (6 EAP) which main goal is to decouple environmental impact from economic growth through better resource efficiency and resource and waste management.

■ Possible recommendations

Based on the current situation and future trends, the following recommendations can be made:

- Continue the effective implementation of the WEEE and RoHS Directives, and extend the WEEE directive to non-traditional ICT products, i.e. everyday object which integrate electronics (embedded ICT in “smart products”).

The problem of ICT embedded in vehicles is already addressed by the WEEE/ROHS /End-of-life of vehicles¹³⁵ directives however, for some other “smart” products it is not the case: e.g. for. smart wearable,¹³⁶ smart packaging equipped with RFID tags (small microchips) it is not the case. The **invisibility of pervasive computing components** in many products will make it more difficult for consumers to differentiate between electronics and non-electronics. Therefore waste separation by the end-consumers will be very difficult. As a consequence, the **risk of uncontrolled disposal** of toxic substances as a part of household waste could counteract the goals of the European WEEE Directive. If no adequate solution is found for the end-of-life treatment of the electronic waste generated by millions of very small components, precious raw materials could be lost and harmful pollutants emitted to the environment¹³⁷. However, little knowledge on how pervasive computing will develop (path uncertainty), combined with little knowledge base for the LCA of electronic products (data uncertainty), and non consistent knowledge about future usage patterns (as these applications are just emerging), makes it difficult to draw quantitative forecasts of environmental impacts. A separate collection of single electronic components is

¹³⁴ <http://www.mar.partners.extranet.microsoft.com/>

¹³⁵ Directive 200/53/EC

¹³⁶ Also called « i-wear » it refers to a concept of wearable computing which means that piece of clothing are embedded with electronic devices (microprocessors, sensors, batteries).

¹³⁷ See case studies on i-wear and smart packaging in A. Köhlern L. Erdman. Expected Impacts of Pervasive Computing. 2004. http://www.empa.ch/plugin/template/empa/*/51472/---/l=2

however not realistic in the future as it would require tremendous logistic and technical efforts which could require huge amounts of energy. Therefore, **research** should be undertaken in order to assess for which waste fractions a separate treatment makes sense (i.e. in the case of packaging preliminary case studies shows that RFID tags would not be too problematic when recycling cardboard as impurities can be removed in the pulper (as it is already the case for copper paper clips), but could be challenging for glass recycling). Also measures to **support for intelligent systems for recycling and other forms of recovery**, thereby decreasing the e-waste fraction that goes to final disposal and incineration should be encouraged. Also, the “pervasive computing vision” is far from being realised yet, there is potential to reduce the risks by taking into account environmental effects in the design phase (see next section on production phase).

- **Provide incentives for producers to design and sell ICT products with a longer lifespan.** However, this should not impair innovation and product performance and limit the development of sales models which make the ICT products obsolete after a short period of time (e.g. mobile phones with short subscription packages).

1.4.1.2 Production phase

- Impacts of the production phase of ICT products and components

Current ICT products and infrastructure equipment rely on a variety of different components including micro-chips, semiconductors, printed wiring boards, cathode ray tubes, and batteries.

Major issues related to the production phase of ICTs include:

- Large material flow
The material extraction and component manufacturing involve particularly large material flows. This is mainly due to the use of rare compounds in electronics such as germanium, arsenic, indium, tantalum, etc.
Some estimates indicate that for some ICT products, 98 % of the material flows occur during the manufacturing process or preceding stages of production, in the form of waste (and only 2 % flow into the product)¹³⁸. At component level, a previous assessment of microchip production indicates that the total mass of materials and resources used in manufacturing a 2 g microchip is almost 2 kg (factor 1000)¹³⁹.
- Material and energy intensive manufacturing and production processes

¹³⁸ Fichter, Behrendt. *Sustainable business innovation in the internet economy*

¹³⁹ More specifically a 32 MB DRAM memory chip of 2 g requires 1.6 kg of fossil fuels, 27 g of various chemicals, 700 g of elemental gases, and 32 kg of fresh water. Source: Williams. *Energy Intensity of Computer Manufacturing: Hybrid assessment combining process and economic input-output methods*. Environmental Science and Technology 38 (22) :6166-6174 . 2004

Also the manufacturing of many of electronic components involve significant environmental impacts. For example, semiconductors manufacturing causes significant amounts of air emissions (e.g. acid fumes, volatile organic compounds), water emissions (e.g. solvents, cleaning solutions, acid, metals) and wastes (e.g. silicon, solvents)¹⁴⁰. Semiconductors are based on rare compounds and synthetic materials. The extraction of raw materials and the synthesis of material involve material and energy intensive processes producing huge amounts of mining waste. Also, the growing demand for material purity implied by miniaturisation (emerging nano-technologies and nanoelectronics) of semiconductors requires higher amounts of energy¹⁴¹.

Material consumption for the ICT infrastructures (communication lines, servers, etc.) is also significant.

- Raw materials availability

Moreover, some of the raw materials included in ICT devices being rather “exotic”, the supply and availability of these materials could represent a problem (e.g. tantalum for which a temporary shortage occurred in 1999-2001¹⁴²).

In terms of primary energy used during production phase expressed in mega joules, the EuP lot 3, 4 and 5 studies provide insights on the relative significance of the production phase compared to the end-of-life, distribution and use phase. Results show that the production phase is negligible in terms of primary energy consumption (Figure 34) except for low energy consuming products such as some types of ink jet multi functional devices.

The use and end-of-life phase of ICTs are a growing problem, while production seems to be stable and, furthermore, of decreasing importance within the geographical boundaries of Europe¹⁴³. Production will increasingly move outside the EU, but the environmental impacts of production should be taken into account, regardless of where the manufacturing takes place.

- Related existing and future policy frameworks, and voluntary initiatives

The related existing policy framework, complementary to the WEEE and RoHS directives, is the Directive 2005/32/EC on the eco-design of Energy-using Products (EuP) which will draw future implementing measures for the design of EuPs, including ICT devices.

¹⁴⁰ EPA 1995

¹⁴¹ A. Plepys. *Information and Communication Technologies’ role in productivity changes, rebound effect and sustainable consumption*. Lund University 2001

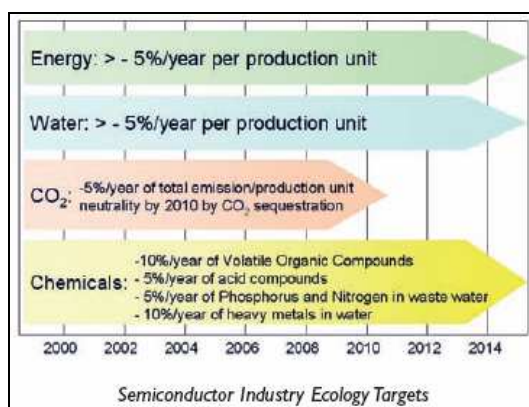
¹⁴² Only a few companies extract tantalum mostly in the Democratic Republic of Congo and in Australia

¹⁴³ Hilty and al. *The future impact of ICT on environmental sustainability. Fourth Interim Report. Refinement and quantification*. Institute for Prospective Technological Studies (IPTS)

Business led initiatives have been trying to improve the environmental performance of the production phase of ICTs as well:

- In 1997, the European semiconductor industry set goals, which go beyond the Kyoto requirements in terms of CO₂ emissions and also target the elimination of environmentally unfriendly materials, and the reduction of primary resources consumption per unit of wafer (i.e. semiconductor) produced (Figure 35).

Figure 35: European Semiconductor industry ecology targets¹⁴⁴



- In 2003, Xerox had committed to reduce its greenhouse gas emissions, and already announced a reduction of energy consumption in facilities, manufacturing operations and across service and sales vehicle fleet. In 2006, energy consumption decreased 13% compared to 2005 and by 21% compared to 2002¹⁴⁵.
- In October 2007, IBM announced an innovative new semiconductor wafer reclamation process pioneered at its Burlington, Vermont manufacturing facility (USA). The new process uses a specialized pattern removal technique to **repurpose scrap semiconductor wafers** (thin discs of silicon material used to imprint patterns that make finished semiconductor chips for computers and other consumer electronics) **to a form used to manufacture silicon-based solar panels**¹⁴⁶. Through this new reclamation process the intellectual property from the wafer surface is more effectively removed, making the wafers available either for reuse in internal manufacturing calibration as "monitor wafers" or for sale to the solar cell industry, which must meet a growing demand for the same silicon material to produce photovoltaic cells for solar panels.
- HP, IBM, Dell and others have developed an Electronic Industry Supplier Code of Conduct to reduce to involve the whole supply chain in energy efficiency actions.

¹⁴⁴ ENIAC (European Technology Platform of nanotechnology) and ESIA (European Semiconductor Industry Association)

¹⁴⁵ http://www.xerox.com/Static_HTML/citizenshipreport/2007/nurturing-page5-3.html

¹⁴⁶ The new process was recently awarded the "2007 Most Valuable Pollution Prevention Award" from The National Pollution Prevention Roundtable (NPPR).

- Sharp's commitment extends beyond the concept of 'green' products, the concept of « green factories » through its award-winning 'Super-Green Factory' policy that lower the burden on the environment of its own manufacturing processes

■ Possible recommendations

The impacts of the production phase are already covered by the EuP directive. Further, the **sharing and leasing of ICT equipment** should be encouraged to increase the number of users per equipment in e.g. offices and administrations. This can be done by promoting an environmentally sound and economically viable shift from products to services by improving the dissemination of information to companies on the product service systems (PSS) concept and on successful case studies. **The existing and developing policy framework (e.g. IPP and EuP) should be apt to address this issue and support implementation.**

1.4.2. ASSESSMENT OF THE BUSINESS OPPORTUNITIES

With the re-launch of the Lisbon Strategy in 2005, the EU has taken on an immense transition task to catch-up with the progress towards the 2000 Lisbon objectives and to build a globally competitive knowledge-based economy to create more jobs and growth. ICTs are one of the key sectors to achieving this goal. It employed about **4% of the EU 27 workforce in 2007¹⁴⁷** and has a **high growth potential** in itself. While the Western European IT market is expected to grow at an annual average rate of 6.1% until 2008, the Central and Eastern European markets are expected to swell by 13.2%¹⁴⁸.

This section provides some insights on the possible effects of ICT market growth on EU employments by sector of innovation (e.g. photonics, nanotechnology).

The European ICT platforms (NEM, eMobility, NESSI, ARTEMIS and ENIAC, to which the Photonics 21 platform can be added) together call for support for Research and Development from national and regional sources, as well as the European Commission in a well coordinated manner, as **each Euro spent in Research and Development is guaranteed to have a significant impact on growth and employment.**

Data is taken from projected estimates from diverse European Technology Platforms which all emphasise on the part that the ICT has to play to help Europe achieve the Lisbon Objectives.

¹⁴⁷ EC press release

<http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/392&format=HTML&aged=0&language=EN&guiLanguage=en>

¹⁴⁸ DG TREN-ICT Task force http://www.eeca.eu/data/File/ESIA%20Publications/icttf_report_exe_theme_paper.pdf

1.4.2.1 ARTEMIS: Electronic embedded systems

The design and production of Embedded Systems has become a major driver for the European IT industry. The impact of this increase can be best illustrated by the automotive sector. This sector alone has a turnover of € 500,000 million/year and employs 2.7 million people in the EU. Given that 20% of the value of each car today is due to embedded electronics and that this is expected to increase to an average of 35-40% by 2015, more than 600.000 new jobs will be created in Europe in the automotive industry (source: ARTEMIS)

1.4.2.2 ENIAC: Nanoelectronics

This platform includes the semiconductors technologies. In a document published by The EU ICT Task force report¹⁴⁹, the semiconductor industry is a **key industry in Europe** for the entire ICT innovation cycle, with a major enabling role and specific R&D, manufacturing situation. Specific measures are recommended to securing a global level playing field with other industrialised regions in the world, to ensure stronger support for manufacturing and strengthen ICT clustering potentials.

1.4.2.3 eMobility

This platform relates to mobile and wireless communication technologies. The eMobility platforms projects that the potential for market growth is unlimited considering the trend to have more and more mobile handsets. Global wireless subscribers are estimated to have increased increase from 1.3 billion (Dec 2003) to over 1.8 billion in 2007 and employment in the mobile and wireless sector is expected to grow from the current level of 4 million people to 10 million people in 2010.

1.4.2.4 NESSI: ICT infrastructures and software

Within the ICT sector, the software and IT services takes a significant share of the EU economy, representing between 5 and 6 % of the European GDP in 2004 (from banking sectors, governments, to automotive sectors, health and logistics). Moreover, the sector of IT services and software stimulates the creation of high skilled jobs (high added value, sustainable jobs).

1.4.2.5 Photonics²¹

The photonics industry supports the development of ICT products and technologies such as LCD monitors, OLED displays, LED lighting, imaging equipment, CD, DVD, optical networks, etc. This sector is expected to play a growing part in Europe's overall economy. European photonic production is now equivalent to that of microelectronics in Europe and is expected to exceed it soon. It has grown by 12 % in 2006; reaching 49,000 million Euros. The sector employs 246,000 people in Europe, not including sub-

¹⁴⁹ http://www.eeca.eu/data/File/ESIA%20Publications/icttf_report_exe_theme_paper.pdf

contractors. Over 5000 companies are involved in the manufacturing of photonics, most of them small and medium sized enterprises. For the period 2005 to 2015, an annual growth rate of 7.6 % of the world photonics market is predicted (see Figure 36 and Figure 37).

Figure 36: Photonics world market forecasts¹⁵⁰

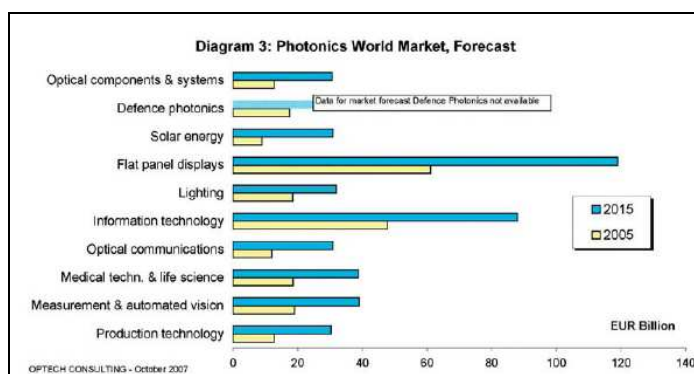
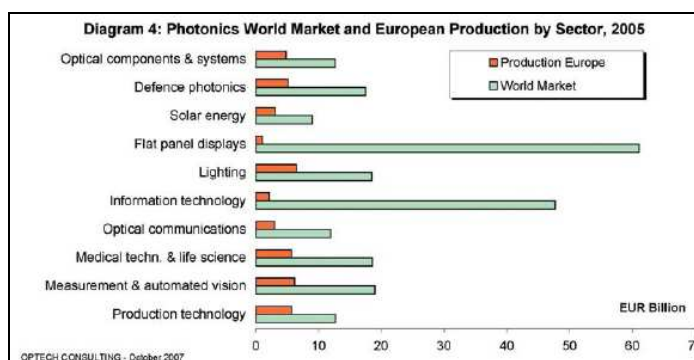


Figure 37: European share in worldwide photonics production¹⁵¹



1.4.3. CONCLUSIONS – ASSESSMENT OF BUSINESS OPPORTUNITIES

Increasing human resources in science and technology is one of the key targets of the Lisbon agenda in order to boost competitiveness and increase growth in the European economy. According to the European Commission, the ICT industry alone contributes to one fourth of EU's total growth and **4% of its jobs (2007)**. Yet the sector is set to face a skills shortage of some 300,000 qualified engineers.

In order to avoid slowing down the European economic growth and to avoid running the risks of falling behind its Asian competitors, initiatives to encourage carriers in ICT are already in the pipeline: e.g. recently, the Commission, together with leading technology companies, is exploring the potential for women in the ICT sector in a drive to avoid a predicted shortage of some 300,000 qualified engineers by 2010.

¹⁵⁰ Photonics21. Economic Impact report 2007

¹⁵¹ Ibid

Encouraged by the experience, the Commission together with the private sector is to draft a "European Code of Best Practices for Women in ICT" by next year's Women's Day.

1.5. CONCLUSIONS

The ICT sector represented 8 % of the EU 25 total electricity consumption for the year 2005 and is estimated to reach 10.5 % in 2020 in a BAU scenario against 7.4% in an Eco-scenario. Results for EU 27 are estimated to be approximately the same. In terms of equivalent CO₂ emissions, the ICT sector represented 2% of the total EU 25 CO₂ emissions and is estimated to reach 4.2 % in 2020 in a BAU scenario against 3 % in an Eco-scenario.

If consumer electronics such as TVs (incl. Set-Top-Boxes), audio systems and VCR/DVD players are excluded, the energy consumption of ICT amounts to a total of 118.6 TWh in EU 25 i.e. a share of 3.1 % of the total EU 25 electricity consumption for the year 2005; and is expected to reach 245.1 TWh in 2020 in a BAU scenario (6.3 %) against 185.2 TWh (4.8 %) in a Eco-scenario.

In EU 25, in terms of equivalent CO₂ emissions, the ICT sector without consumer electronics was estimated to represent 54.3 Mt CO₂ equivalent in 2005 (1.1 % of the EU 25 total CO₂ equivalent emissions for the year 2005) and is expected to reach 112.3 Mt CO₂ equivalent in a BAU scenario and 84.9 Mt CO₂ equivalent in the Eco-scenario (respectively 2.5% and 1.9 % of the total EU 25 projected CO₂ equivalent emissions, assuming a reduction of 20% compared to the 1990 level).

The existing and developing frameworks, business initiatives, voluntary measures, and the current research programs seem to be apt to address the issues related to the production of: more efficient ICT equipments (devices and infrastructure), more long lasting equipments, more products being recyclable and reusable and to reduce the amount of ICT waste being land filled or incinerated.

However, voluntary measures to better supply customers with sufficient information enabling them to make more sustainable decision when selecting ICT equipment could be reinforced (i.e. extend the scope of products covered by energy star and eco-label), also the take up of efficient ICT equipment could be further encouraged in order to reduce the future electricity footprint of the ICT sector.

The total electricity consumption of the ICT sector should however be put into perspective with the potential energy savings that the use of ICT technologies can enable in other sectors such as the buildings sector, the energy sector, the industry and in the service sector. In this respect, the following tasks will assess the potential energy savings which could be reached through the use of diverse ICT application in different sectors of the European economy, while considering the possible environmental effects, and business opportunities which might arise from the increased use of ICT applications in various sectors.

2. Task 2: Discussion and Quantification of ICT Applications Enabling Energy Efficiency – 2020 Outlook

2.0. INTRODUCTION

This document is the final document for Task 2 report of the study on the impacts of ICT on energy efficiency in Europe. It contains the sub-tasks 2.1, 2.2 and 2.3. related to the study of energy efficiency enabled by ICT application in the buildings sector, in the industrial equipment and automation sector, and in the energy grid sector.

As stated in the Task 1 document, Information and Communication Technologies (ICT) can affect the natural environment directly or indirectly and such effects can be of following three types:

- First order effects include the direct environmental impacts caused by an ICT equipment during its whole life cycle (assessed in Task 1)
- Second order effects relate to the application of ICT in other sectors, thus causing an indirect impact on the environment e.g. the environmental impact of a production process can be different when an ICT technology is applied to manage or monitor the process.
- Third order effects are macro-level indirect effects resulting from structural and behavioural changes and adaptation to the ICT services as a part of everyday life and business (assessed in mostly in Task 3)

As such, this Task 2 focuses on the second order effects of ICT which relate to the application of ICT in other sectors (e.g. production processes) thus causing an indirect impact on the environment.

In order to analyse and estimate the potential that ICT-based application can provide to improve the energy efficiency in these sectors, each sub-task proposes to develop:

- Baseline scenarios (reference scenario): mainly based on literature data, these scenarios do not take into account the increase in the use of ICT-based application. These scenarios are the reference against which to evaluate the alternative scenarios¹⁵².
- Business-as-Usual scenarios (BAU): which assume continuity is maintained considering the current situation and trends
- Eco-scenarios: which assume that there is a push for ICT-based energy efficient solutions.

¹⁵² In Subtask 2.3. on energy grids, we assume that the baseline scenario is the same as the BAU scenario, therefore no baseline scenario was used

In addition, where no solid quantified data could be obtained, “low”, “medium” and “high” hypotheses were used in order to provide a reasonable range of data and order of magnitude.

2.1. SUBTASK 2.1: LOW ENERGY BUILDING

2.1.1. INTRODUCTION

This task has the objective to provide data on the current status of energy consumption of buildings and the potential of ICT applications in support of higher energy efficiency. The focus is placed on the assessments of latest technologies and applications for ICT-enhancement in the field of¹⁵³:

- Heating, ventilation and air conditioning (HVAC)
- Lighting and security systems
- Large electrical equipment including elevators, escalators, white goods

For each of these three topics the study provides:

- Comparative market and energy consumption data (baseline scenario)
- Technical status and trends
- Case studies on ICT applications with energy saving potential

Finally we summarise and discuss the findings of the study which includes the following tasks:

- Systematisation of the identified technical trends
- Qualitative and quantitative assessment of energy saving potential (scenario)
- Evaluation of policy options

2.1.2. HEATING VENTILATION AND AIR CONDITIONING (HVAC)

2.1.2.1 Basic data on building infrastructure in Europe

The energy consumption of buildings is mainly related to passive and active heating systems, ventilation and cooling, lighting and security, large electrical and electronic equipment, as well as individual power supply. In order to allocate energy consumption and improvement potentials, the following basic data on population, number of buildings, floor space, and energy use in the European Union have been compiled:

¹⁵³ Please notice that the topic of power (co-)generation and the power supply system is not part of this assessment. It will be discussed in the subtask 2.3.

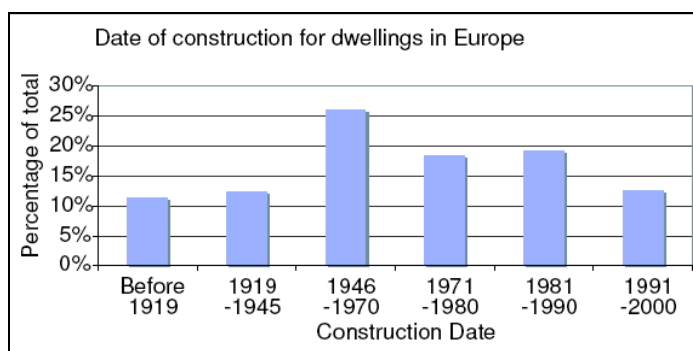
- Population of the EU-27 member states in 2005 was approximately 488 million people according to EUROSTAT yearbook 2006/2007. The EU-15 population amounts 78.8% of total and EU-5 (Germany, United Kingdom, France, Spain, and Italy) still represents 62.3% of total population.
- Number of households in EU-27 is approximately 210 million with 2.3 people per household.
- Number of dwellings in Europe is around 176 million. This number was found in the Human Settlements Bulletin published by the United Nations Economic Commission for Europe.
- Residential floor space: According to [AERE 2006] the average living floor space in the EU has increased over the past decades to 94 m².¹⁵⁴ The EU residential floor space can be calculated to be 16.5 billion m² if we assume a number of 176 million dwellings or to be 19.7 billion m² if we assume 210 million households in Europe. Similar figures are provided in the final report on “Energy Efficiency in Buildings” (EEB), a WBCSD supported project by LAFARGE and United Technologies Corporation. According to this report, the residential floor space in EU-15 amounts approximately 15 billion m².¹⁵⁵ Assuming that EU-15 is 78.8% of total population the resulting residential floor space for EU-27 would be 19.0 billion m². In conclusion we assume that the EU-27 residential floor space is about 17 to 19 billion m².
- Commercial floor space: According to the same study by LAFARGE, the EU-15 commercial floor space roughly amounts to 7 billion m².¹⁵⁶ The actual EU-27 commercial floor could be assumed to be 20% higher resulting in 8.5 billion m² in total.
- Age of the buildings is considerably old with over 50% of the dwellings constructed before 1970 and around 27% before 1945. Many buildings have been renewed and are in fact retrofits. A recent study by Pascal Leormand (AERE 2006) on “Very low energy houses” provides the following age structure for dwellings in Europe.

¹⁵⁴ Lenormand et al (AERE 2006): Very Low Energy Houses, p. 5.

¹⁵⁵ Reference year is 2003. Data based on the US Energy Information Administration (2006): Annual Energy Outlook 2006.

¹⁵⁶ Reference year is 2003. Data based on the US Energy Information Administration (2006): Annual Energy Outlook 2006.

Figure 38: Age of dwellings in EU (Source AERE 2006, 5)



2.1.2.1 Comparative market and energy consumption data for HVAC

According to a recent WBCSD “Report on Energy Efficiency in Buildings” the worldwide energy consumption for buildings will grow by 45% from 2002 to 2025.¹⁵⁷ The report estimates that **buildings account for about 40% of energy demand** with 33% in commercial buildings and even 67% in residential buildings.

Residential HVAC Energy Consumption for 2005 and 2020

According to the latest update of the “European Energy and Transport Trends to 2030” [DG TREN 2008]¹⁵⁸ accounts Heating, Ventilation, and Air Conditioning (HVAC) for the main part of residential energy consumption. For 2005 they allocated 202.6 Mtoe or 66% of total to HVAC energy consumption. The 2020 forecast indicates a further increase to 215.0 Mtoe which equals however only 64% of total (see Table 79).

Table 79: EU-27 residential energy consumption by use (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
Residential by use	%	Mtoe	%	Mtoe
HVAC	66,0	202,6	64,0	215,0
Water heating / cooking	22,0	67,5	21,4	72,0
Lighting	4,5	13,8	4,5	15,0
EEE/ICT	7,5	23,0	10,1	34,0
Total	100,0	307,0	100,0	336,0

Detailed data on the structure or allocation of energy consumption for EU households are not available. The HVAC energy consumption is related to all sorts of fuel including gas, liquid and solid fuels but also district heat and renewable (e.g. solar). The proportion of electricity consumption is rather small although expected to further increase in total until 2020. [JRC 2006] allocates 35% to 40% of residential electricity

¹⁵⁷ World Business Council for Sustainable Development (WBCSD, 2007): Energy Efficiency in Buildings – Business Realities and Opportunities.

¹⁵⁸ [DG TREN 2008] European Commission Directorate-General for Energy and Transport: European Energy and Transport - Trends to 2030, Update 2007, Belgium 2008.

use to HVAC and water heating which equals 280 TWh to 320 TWh for the year 2005.¹⁵⁹ With respect to the year 2020, [DG TREN 2008] expects an increase in electricity related energy consumption (see Table 80).

Table 80: EU-27 residential energy consumption by energy source (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
Residential by energy source	%	Mtoe	%	Mtoe
Electricity	23,0	70,6	26,0	87,4
Renewables	10,0	30,7	11,0	37,0
Gas	40,0	122,8	40,0	134,4
District Heat	7,0	21,5	6,0	20,2
Liquid fuels	18,0	55,3	15,0	50,4
Solid fuels	2,0	6,1	2,0	6,7
Total	100,0	307,0	100,0	336,0

Regional differences in HVAC / water energy consumption

Annual energy consumption in residential buildings according to different regions in the European Union [Hannus 2008]¹⁶⁰:

- 50-100 kWh/m² in Northern Europe
- 100-250 kWh/m² in Western Europe
- 250-400 kWh/m² in Central and Eastern Europe

This is interesting information; however, it has to be put into perspective:

- Which EU member states are allocated to these three areas?
- What is the number of dwellings or average floor space in these areas?
- What is the unit (kWh/m²) means in terms of energy? Is it a total energy equivalent (1 Mtoe = 11.63 TWh) or just electricity consumption?

The following simplified assumption has been made in order to use the data:

- Northern Europe (3 Scandinavian EU members Denmark, Sweden, and Finland have the highest improvement level in terms of energy efficient HVAC)
- Western Europe (EU-15 without Denmark, Sweden, and Finland have an average improvement level in terms of energy efficient HVAC)
- Central and Eastern Europe (EU-27 without EU-15 have the lowest improvement level in terms of energy efficient HVAC)
- Number of households according to population (2.3 persons per household)

¹⁵⁹ [EUROSTAT 2007] estimates the residential electricity use for EU-27 in year 2005 to be 799.2 TWh.

¹⁶⁰ [Hannus 2008]: Matti Hanus (VTT), Alain Zarli (CSTB): Smart Buildings for Energy Efficiency, "Information and Communication Technologies for Energy efficiency" Conference, EUSEW - EU Sustainable Energy Week 2008, Brussels, January 2008.

- Average household floor space 94 m² [AERE 2006]
- The unit (kWh/m²) is a total energy equivalent

The resulting figures of these scenarios are shown in Table 81 below. The figures are not convincing. Even the best case (222.4 Mtoe) is not really comparable to our baseline estimate (202.6 Mtoe) which derived the statistical data of [DG TREN 2008].

Table 81: Regional differences in residential HVAC energy consumption (2005)

Regional scenario		best case			worst case		
Level of improvement	Regional Scope	Number of households [Mio]	Energy consumption per area [kWh/m ²]		energy consumption per year [Mtoe/a]	Energy consumption per area [kWh/m ²]	energy consumption per year [Mtoe/a]
high	3 Scandinavian Member States	8,5	50,0		3,4	100	6,9
average	EU-15 (without Scandinavia)	158,7	100,0		128,2	250	320,6
low	EU-27 without EU-15	44,9	250,0		90,8	400	145,2
	Total	212,1			222,4		472,7

But this scenario approach is nevertheless very useful for an impact assessment. What we have to do is tuning the data allocation according to the statistical figure. A quick analysis shows that the household allocation to the category “high level of improvement” is only 4% of EU-27 total. If we compare this number with the age statistic of European buildings [AERE 2006] we see that at least 12.5% of total have been built after 1991 and approximately 19.0% in the time between 1981 and 1990. It is justified to assume that a larger part of these buildings have already a quite high level of HVAC energy efficiency. For our scenario we make the pragmatic assumption that 25% of all EU households have a high level of HVAC energy efficiency.

Regarding the lower level the number indicate that 21% (44.9 Mio households) are suboptimal. Keeping in mind that approximately 27% of buildings are older than 1945 this seems to be a realistic figure. In order to further simplify the scenario we assume that 20% of all EU households have a low level of HVAC energy efficiency. According these assumptions adjusted the scenarios. The results are shown in Table 82 below.

Table 82: Regional adjusted residential HVAC energy consumption (2005)

Regional adjustment 2005		best case			worst case		
Level of improvement	Regional Scope	Number of households [Mio]	Energy consumption per area [kWh/m ²]		energy consumption per year [Mtoe/a]	Energy consumption per area [kWh/m ²]	energy consumption per year [Mtoe/a]
high	25% of EU-27	53,0	50,0		21,4	100,0	42,8
average	55% of EU-27	116,7	100,0		94,3	250,0	235,8
low	20% of EU-27	42,4	250,0		85,7	400,0	137,1
	Total	212,1			201,4		415,7

The regional adjusted scenario for 2020 (with the same assumption as for the year 2005, but assuming increased population and therefore increased number of households) results in an energy consumption of 205.0 Mtoe per year as best case, 423.0 Mtoe per year as worst case.

Table 83: Regional adjusted residential HVAC energy consumption (2020)

Regional adjustment 2020		best case			worst case		
Level of improvement	Regional Scope	Number of households [Mio]	Energy consumption per area [kWh/m ²]		energy consumption per year [Mtoe/a]	Energy consumption per area [kWh/m ²]	energy consumption per year [Mtoe/a]
high	25% of EU-27	54,0	50,0		21,8	100,0	43,6
average	55% of EU-27	118,7	100,0		95,9	250,0	239,9
low	20% of EU-27	43,2	250,0		87,2	400,0	139,6
	Total	215,8			205,0		423,0

These adjusted scenarios for residential HVAC will be used in chapter 2.1.2.10 for the assessment of the energy saving potential.

Service Sector HVAC Energy Consumption for 2005 and 2020

According to the latest update of the “European Energy and Transport Trends to 2030” [DG TREN 2008] accounts HVAC for offices and commercial buildings in the services sector¹⁶¹ for the main part of energy consumption as well. The total energy consumption of HVAC is in comparison to the residential sector (households) smaller. The energy consumption of HVAC in the service sector amounts to 82.0 Mtoe for the year 2005, which is 57% of the total energy consumption [DG TREN 2008]. The 2020 forecast indicates a further increase to 92.5 Mtoe which equals however only 53% of total (see Table 84).

However, the proportion of cooling energy is larger in comparison to the residential sector. Cooling related to air conditioning of offices and server rooms is expected to increase from 9.6 Mtoe in 2005 to 15.4 Mtoe in 2020.

Table 84: EU-27 service sector energy consumption by use (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Services by use</i>	%	Mtoe	%	Mtoe
HVAC	56,6	82,0	53,0	92,5
Other Heat	22,4	32,5	19,5	34,0
Lighting	3,8	5,5	3,4	6,0
EEE/ICT	17,2	25,0	24,1	42,0
Total	100,0	145,0	100,0	174,5

Detailed data on the structure or allocation of energy consumption for the EU service sector, similar to data for the residential sector, are not available for the service sector. The HVAC energy consumption is related to all sorts of fuel including gas, liquid and solid fuels but also district heat, renewable and electricity (see Table 85).

¹⁶¹ The services sector accounts for only 12% of total final energy demand but produces 70% of total value added in the EU economy.

Table 85: EU-27 service sector energy consumption by source (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Services by energy source</i>	%	Mtoe	%	Mtoe
Electricity	42,0	60,9	47,0	82,0
Renewables	1,0	1,5	3,0	5,2
Gas	32,0	46,4	32,0	55,8
District Heat	7,0	10,2	7,0	12,2
Liquid fuels	16,0	23,2	10,0	17,5
Solid fuels	2,0	2,9	1,0	1,7
Total	100,0	145,0	100,0	174,5

Industry Sector HVAC Energy Consumption for 2005 and 2020

Specific data on the HVAC related energy consumption in the industry sector could not be obtained. We therefore exclude the HVAC application in industry in this chapter on low energy buildings and cover the improvement potential in the following chapter on electrical drivers, motors, pumps and ventilators due to the fact that energy consumption in HVAC is mostly related to these large electrical components.

For comparison we solely add at this point basic economic data for total EU energy consumption (see Table 86) according to the latest update of the report on “European Energy and Transport Trends to 2030” [DG TREN 2008].

Table 86: EU-27 all sectors energy consumption (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Final demand by sector</i>	%	Mtoe	%	Mtoe
Industry	27,8	324,5	27,3	367,7
Residential	26,3	307,0	24,9	336,0
Services/Agriculture	14,9	173,7	15,2	205,5
Transport	31,0	361,7	32,5	438,6
Total	100,0	1.166,9	100,0	1.347,8

In terms of electricity consumption the reference data set (see Table 87) has been calculated based on [EUROSTAT 2007] and [DG TREN 2005].

Table 87: EU-27 all sectors electricity consumption (2005 and 2010)

EU Electricity Consumption	2005	2005	2020	2020
<i>Final demand by sector</i>	%	TWh	%	TWh
Industry	41,0	1.130,0	36,0	1.430,1
Residential	29,0	799,2	32,8	1.302,9
Services/Agriculture	27,0	744,1	29,5	1.171,9
Transport	3,0	82,7	1,8	72,7
Total	100,0	2.756,0	100,0	3.977,7

2.1.2.2 Technical status and trends

The rise of fuel and energy costs has lead to technical innovation for residential and commercial HVAC applications since the first global oil crises in 1973. A second wave occurred in the 1990th when the growing cost and environmental awareness of consumers merged with the opportunities of the IT revolution. The industry acted on

these conditions by developing further innovations including the application of ICT in HVAC systems. On a technical level a general differentiation of passive and active HVAC systems is made.

- Passive system approach includes the design and construction of the building. The intention is to minimise thermal losses through surfaces such as walls and windows as well as between surfaces through the use of advanced insulation materials or jalousies in the case of windows.
- Active system approach includes the installation of low energy HVAC equipment in conjunction with an effective sensor-based control system. Active HVAC systems utilise temperature, humidity, light, or air flow sensors for condition monitoring. In combination with an algorithm-based controller unit the active system ensures demand optimised operation of HVAC equipment such as heaters, air conditioners, boilers, and heat exchangers. The necessary data transmission between sensors and controller is wired or wireless with respective protocols.

Sensor-based monitoring and control is already utilised to support the efficient use of active HVAC systems today. In the future, ICT will further support the effective interaction of the single elements of the active system. It seems to be a trend that ICT is also used in order to create smart passive systems. A further trend is to combine residential heat and power generation in one system. Such Combined Heat and Power (CHP) modules require sophisticated ICT-enhanced process measurement and control technology.¹⁶²

Water heating (hot/warm water) requires energy. Typically, carbon energy sources such as electricity, fuel and gas (burner) are utilised in dwellings. Solar water heating systems are alternative solutions which have a higher demand on supporting infrastructure such as circulation pumps and energy conversion control. The control of water temperature, demand according to the time of the day, and the throughput (water flow) are areas where mechanical and ICT-based control systems can support a more efficient water utilisation. However, studies indicate that the user behaviour (conscious use of water) has the highest impact.

The following case studies exemplarily discuss the principles for the application of ICT (functionality) in the context of energy efficient HVAC systems.

2.1.2.3 Case study: Residential HVAC – Passive and active thermal wall insulation

Topic and technological concept

This case study introduces an ICT enhanced smart passive HVAC system based on vacuum insulation panels (VIP). The panels provide extremely low thermal conductivities and are therefore used for building wall insulation. The vacuum

¹⁶² Bruno, Joan Carles (2006): THE EUROPEAN GREEN BUILDING PROGRAMME - Technical Module on Combined Heat and Power, Universitat Rovira i Virgili National.

insulation panels are built from open pore materials like pressed powder boards, glass fibres or open cell organic forms. The core materials are wrapped in a high gas barrier film using a special procedure and then evacuated and sealed. In case of thermal conductivity of VIP produced by va-Q-tec (va-Q-vip) is only one tenth of the conductivity of conventional indoor insulation materials like mineral wool or foams ca. 0.004 to 0.005 W/mK compared to 0.040 W/mK. The life time of the VIP is critical and relates to the increase of gas pressure within the panel. The va-Q-tec products for indoor building insulation have an initial gas pressure of 1 mbar and still achieve ca. 0.007 W/mK at 100 mbar. With an average increase of gas pressure of 1 mbar/year a lifetime of up to 50 years is possible. In order to check the internal gas pressure, va-Q-tec is integrating a sensor-chip which can be read-out externally with a scanner.¹⁶³

ICT Application

A step further to ICT-enhanced smart building insulation is based on the vacuum insulation panel technology. The Bavarian Centre for Applied Energy Research (ZAE Bayern) is conducting research on switchable VIP. A similar approach is used in the application of so called Phase Change Materials (PCMs) for thermal energy storage in walls or building insulations.¹⁶⁴

The idea is to regulate the in-house temperature by controlling and actively switching the thermal conductivity of the panels. ICT-based sensors and control devices are needed in such a system to achieve efficiency. The ICT support system comprises of outside and in-house temperature sensors, possibly internet-based weather information, and sensor/actuator control system with respective communication protocol (bus protocol). The ICT applications support the time-critical and demand-specific control of the insulation panels, which in turn determines the overall energy efficiency and lifetime quality of the passive HVAC system.

Energy Saving Potential

The energy efficiency potential of ICT-enhanced passive HVAC systems has not been quantified in the literature. Commercial descriptions only qualify the general insulation efficiency of vacuum insulation panels. It is said that ICT provide additional efficiency through **condition monitoring and active control of thermal conductivity**. These are long-term applications with long-term energy trade-offs. The application of ICT in context to passive HVAC is currently very limited. Limiting factors are the potential high costs (feasibility and efficiency is assumed highly individual) and the long-lifetime installations (high quality, safety, reliability and eco requirements).

¹⁶³ The va-q-tec insulation panels have a limited application due to technical properties (you cannot perforate the panel) and the high costs (currently 100 €/m²) which might improve by 30% in the mid-term. Information available online: <http://www.va-q-tec.com>

¹⁶⁴ The Bavarian Center for Applied Energy Research (ZAE Bayern), information available online: <http://www.zae-bayern.de>

2.1.2.4 Case study: Residential HVAC – Switchable mirror film on windows

Topic and technological concept

In recent years, double insulating glasses and heat reflecting glasses have been widely used in order to enhance energy-efficiency by increasing the thermal insulating performance of windowpanes. Light control glasses, however, had been expected to save more energy by effectively controlling light from outside as necessary. One of the problems with conventional light control glasses is that they heat up by absorbing sunlight, reradiating the heat into the room. A newly developed flexible switchable mirror film has solved this problem by controlling sunlight through reflection.

ICT Application

The Japanese National Institute of Advanced Industrial Science and Technology (AIST) announced on November 21, 2007, that it had developed a light-control mirror film, which controls sunlight efficiently and helps increase security by switching between reflective and transparent states with very little voltage.¹⁶⁵ The institute said that the system was successfully built on a 100-micrometer-thick film. Moreover, it can be produced as a thin film, and can be applied to both glass plates and flexible substrates such as plastic. Just by applying the film to existing window glasses, the amount of heat or cooling load inside buildings or cars can be controlled at the flick of a switch.

The new mirror film operates as an electro-chromic system and can be electrically switched between reflective and transparent states by applying a voltage of a few volts. The film is made entirely of solid materials, and thus offers an easy handling, etc. The switching control can be supported by sensors. ICT supported sensors and control have not been mentioned in the press release. However, it seems absolutely feasible to assume that the efficiency of this new film is improved by ICT.

Energy Saving Potential

The newly developed flexible switchable mirror film can control solar radiation effectively, so reducing the cooling load and potentially save energy. The range of applications for this film is expected to expand dramatically in the near future as the switchable mirror film can be stuck on already built window glass of building, cars, etc.

2.1.2.5 Case Study: Residential HVAC – Temperature monitoring and heating control

Topic and technological concept

An efficient HVAC control system is linking today indoor and outdoor temperature sensors, radiators, air conditioners, ventilators, burners, boilers, or heat exchangers in a network. This network is sharing and exchanging data (e.g. on temperature) in order to have an optimal (condition depended) set-up of the different entities. The network communication is based on protocols or field busses. There are currently over 100

¹⁶⁵ AIST: http://www.aist.go.jp/aist_e/latest_research/2007/20071213/20071213.html

different protocols of the first generation of industrial communication (e.g. Profibus, Interbus-S) and second generation of broadband industrial communication (e.g. Ethernet/IP, ProfiNet) available on the market. This situation is reflected by many different solutions already available.

The idea of a single “multi-purpose protocol” is technically not realised yet. The reason for this has to be seen in the parallel development of various technical standards as well as cost, and the market share protection policy by manufacturers.

ICT Application

ICT network solutions for an effective control of traditionally isolated, independently operating HVAC equipment is still an important topic in residential and commercial building infrastructure. ICT and wireless communication technologies in particular provide flexibility and efficiency in terms of:

- Ease of retrofitting or modification over time
- Demand-base maintenance and repair
- Utilisation of equipment from different manufacturers
- Combining mechanical, pneumatic, electrical, and electronic components in a network
- Monitoring and controlling the HVAC system for performance optimisation and energy efficiency

The following examples of residential HVAC controlling units are only a small part of available product solutions in the market. The “Room Temperature Modulation” is a technology used in all Buderus condensing boilers and control units. The ModuLink 250 RF is a wireless thermostat and programmer designed especially for Buderus domestic condensing boilers.¹⁶⁶ This versatile unit has independent heating and hot water control, built in frost protection, a holiday function, and up to 6 different switching points allowing the user total control of their heating system. This energy saving technology controls the output of the boiler according to the temperature of the air in the room, rather than measuring the flow temperature in the boiler. This means the boiler can react almost instantaneously to even the smallest temperature fluctuations, adjust its output accordingly, and maintain comfort levels in the room.

The Buderus Logamatic EMS, 4000 and 2000, a combined boiler-solar controlling unit reduces the amount of the warming starts and lowers the energy consumption.¹⁶⁷ This heating system includes a controller unit linking boiler, solar system and hot water tank by controlling the communication between these single units. The modules SM10,

¹⁶⁶ Buderus: *Die intelligente Regelung denkt mit*, online available at (German): www.buderus.de/Ueber_uns/Presse/Fachpresse/Regelung/Die_intelligente_Regelung_denkt_mit-1737683.html

¹⁶⁷ www.buderus.net/OurProducts/Controls/Logamatic2107/PerformanceDetails/tabid/271/Default.aspx

FM443 and FM244 optimise the output of solar energy and control the solar system by using the integrated temperature difference controlling unit. This function balances the temperature of the collectors with this in the lower area of the storage and decides whether the solar storage can be warmed up by solar energy.

Another example to show energy efficient systems is the circulation pump technology Bosch Heatronic 3 by Junkers.¹⁶⁸ This unit is connected to an outside regulation which controls the pump depending on the weather conditions. Thus the circulation pump only works if it is really necessary. The Junkers solar technology solar inside measures the temperature demand of the water consumption and the heat on the surface of the solar collectors. By calculating the possibility of using the solar heat to warm up the storage this technology is quite energy efficient. The energy saving effect for warm water supply is up to 15%.

Energy Saving Potential

There are many examples for ICT enhanced residential HVAC systems which utilise outdoor and indoor temperature sensors in conjunction with wired or wireless communication for efficient equipment control. The Buderus products do save 10% of fuel and reduce the fuel bills by up to 30%. Junkers' Bosch Heatronic 3 reduces the costs for the supporting electrical energy by 20 to 50 euro per year and the eco circulation pump **reduces the energy consumption for up to 89%.**

2.1.2.6 Case study: Commercial HVAC – Integrated cooling of ICT infrastructure equipment

Topic and technological concept

Passive and active HVAC systems have been holistically modified to specific tasks or conditions in commercial applications and buildings. The cooling or ventilation of electrical machinery, commercial server, and telecommunication equipment is a growing field where energy efficiency is a main aspect in cost-benefit calculations. The following case study focuses on integrated ICT-enhanced HVAC systems for server rooms and data centre.

A practical study on energy efficiency of server rooms and data centre was recently conducted by the German Borderstep Institute in collaboration with main server manufacturers, data centre provider, the BITKOM, and the German Ministry of Environment.¹⁶⁹ In the resulting study report Borderstep concludes that combined measures of optimised server technology (e.g. demand switched CPU) and **HVAC system can lead to an average 30% – and in best cases 50% – increase in total energy efficiency.** The HVAC system design and control has a major impact as the study identified.

¹⁶⁸ www.junkers.com/de/de/presse/presstexte/gas-brennwert/energiesparen_mit_system.html

¹⁶⁹ The Study „Zukunftsmarkt grüne Rechenzentren“ (Future market green data centre) was conducted by Borderstep Institute in 2007. Information available in German: <http://www.borderstep.de>

According to a presentation given by Schnabel AG¹⁷⁰ at conference on green data centre¹⁷¹, the electricity distribution in data centre is as follows:

- 40-60% related to servers incl. power supply and losses
- 20-30% related to ventilation, pumps and lighting
- 15-25% related to cooling
- 5-10% related undistruptive power supply and transformation losses

Depending on the server specifications and their use, the HVAC system consumes almost 50% of total electricity. The reduction of energy consumption in conjunction with an improved HVAC system is complex and consists generally of following measures:

- Improvement of passive HVAC system (e.g. thermal insulation, air flow design)
- Efficient HVAC equipment and alternative energy source (e.g. solar power)
- Dimensioning and demand-oriented operation of HVAC system (e.g. increasing air con threshold to 28°C)
- Eliminate failures by air condition monitoring and smart cooling
- Efficient servers, consolidation of server park, virtualisation (e.g. middle ware)

The best practice examples in the Borderstep study clearly indicate the importance of ICT-based condition monitoring and equipment / operation control for the task of reducing energy consumption.

ICT Application

ICT has a support function. If we take the aspect of cooling as an example, energy savings have been generated over the past years through raising the average operation temperature in data centres from 18°C to 28°C. Some data centre providers even run their rooms without any cooling at 35°C. This practice reduces energy consumption by up to 25%. However, in conjunction to less cooling the ventilation had to be improved in order to guarantee a reliable operation.

An example for ICT-enhanced condition monitoring (simulation) and air condition management (control) is the Thermal Zone Mapping (TZM) in conjunction with the Dynamic Smart Cooling (DSC) technology developed by Hewlett Packard (HP). The TZM enables customers to see a three-dimensional model of exactly how much and where data centre air conditioners are cooling. The DSC solution is based on real-time air temperature measurements from a network of sensors deployed on IT racks. These advanced ICT hardware and software solution continuously adjusts air conditioning

¹⁷⁰ SCHNABEL AG is a globally active firm with 30 years experience in the planning of data centre, safety engineering, building services and network technology. Information online: <http://www.schnabelag.de>

¹⁷¹ Presentation in German Language only: http://borderstep.de/pdf/6_Schnabel.pdf

settings for demand-oriented (optimal) cooling. HP argues that customers can reduce data centre cooling energy costs by up to 45% by using Thermal Zone Mapping and Dynamic Smart Cooling.¹⁷²

Efficient servers, the consolidation of server infrastructure and virtualisation are related issues to the overall improvement of data centre energy efficiency. Although this aspect is highly related to the topic of ICT and energy efficiency it is not directly related to HVAC systems in buildings. Nevertheless it is worth mentioning that, according to HP, blade servers consume 30% less energy in comparison to similar performance rack servers. In terms of server integrated ventilation the new Active Fan Technology consumes 50% less energy than conventional fans. Fujitsu Siemens introduced Demand Based Switching (DBS) for the central processing unit (CPU) and estimated that the DBS can save 25% energy in a typical data base environment. Fujitsu Siemens also promotes ServerView Power Control for consolidation and virtualisation of existing server capacity. The efficient utilisation of the servers in the data centre through ICT middleware may reduce the server's energy consumption by up to 75%.¹⁷³

There are similar examples like the new IBM Cool Blue energy efficiency portfolio for blade servers and their updated version of its PowerExecutive management tool for monitoring data centre energy use. Dell introduced the PowerEdge Energy Smart servers in response to customer demand for products that reduce energy consumption while maintaining high levels of performance. The improved power-to-performance ratio of 25% is due in part to more energy-efficient processors from Intel and AMD as well Low-Flow Fan technology and high efficient power supplies. By partnering with market-leading companies like APC, Liebert, Rittal and Samina SCI, Dell is working to address Data Center inefficiency end-to-end.¹⁷⁴

Energy Saving Potential

The energy performance of servers in data centres but also of mobile phone and network telecommunication equipment is strongly influenced by the holistic approach to the design and control of the HVAC system. According to current publications is the energy saving potential related to an ICT enhanced passive and active HVAC system in the case of commercial servers and data centres **approximately 30% of total energy consumption**. Older studies with respect to mobile communication infrastructure (base transceiver stations) indicated a similar high improvement potential.¹⁷⁵ The counterbalancing factors are the continuous increase of digital data and respective

¹⁷² HP website: http://www.hp.com/hpinfo/newsroom/press/2007/070725xa.html?jumpid=reg_R1002_USEN.

¹⁷³ http://borderstep.de/pdf/7_FujitsuSiemens.pdf

¹⁷⁴ DELL
http://www.dell.com/content/topics/topic.aspx/global/products/pedge/topics/en/pedge_energy_2970?c=us&cs=04&l=en&s=bsd

¹⁷⁵ NIK Roadmap Project. In the internet: <http://www.roadmap-it.de>

data traffic. This will not only lead to a higher utilisation of IT infrastructure (e.g. data centre) it is constantly leading to faster and higher performing IT hardware (e.g. servers, base transceiver stations) with the effect that the energy improvement potential is overcompensated by the new performance.

2.1.2.7 Case study: Commercial HVAC – Integrated control of clean room conditions

Topic and technological concept

The air-conditioning and ventilation of clean rooms consume large amounts of energy. A clean room is an environment that has a low level of environmental pollutants such as dust, airborne microbes, aerosol particles and chemical vapours. More accurately, a clean room has a controlled level of contamination that is specified by the number of particles per cubic meter at a specified particle size. Clean room environment is a growing necessity for manufacturing of micro- and nano-scale system technologies in the semiconductor and electronics industry as well as the chemical and pharmaceutical industry and others. Clean rooms can be very large. Entire manufacturing facilities can be contained within a clean room with factory floors covering thousands of square meters. Clean room HVAC systems are very complex. It includes air conditioning, ventilation, particle filters, and often controls the humidity to low levels, such that extra precautions are necessary to prevent electrostatic discharges. Modern clean room HVAC systems require a considerable amount of energy. Real-time monitoring and control as well as programmable presetting of conditions are essential for energy efficiency of such a system.

ICT Application

The Japanese Yamatake Corporation, one of the world's leading building automation solution providers, developed Infiflex™CR, an energy-saving controller for clean rooms. Yamatake developed a programming-based predictive control based on proprietary mathematical models, which realises fast and precise control of temperature and humidity levels. The potential benefits are substantial, with recovery of investment expected to take only one-and-a-half years. According to Yamatake publication, a reduction of the HVAC energy consumption by approximately 50% can be achieved.¹⁷⁶

The German automation technology provider FESTO addresses energy saving in that respect by monitoring air consumption and flow rate for more efficient compressed air management. FESTO's GFDM monitoring system, consisting of sensors/controller, software-tool VipWin for process visualisation, and a front-end-display, tracks down air leaks by constantly and automatically generated reference data. This data is used for permanent comparison, evaluation of consumption using multi-level thresholds and

¹⁷⁶ Yamatake Environmental Report 2007 http://www.yamatake.com/csr/env_report.html

trend data acquisition. There is no impact on the automation process caused by GFDM, so it is applicable for retro-fitting existing systems.¹⁷⁷

Energy Saving Potential

The energy saving potential is generated through an integrated approach including the passive concept or physical design of the clean room as well the active system of HVAC control. ICT-based monitoring and control for energy efficient HVAC systems is already a common feature in clean room design. The energy saving potential depends on the level of integrated HVAC system design. According to the examples the improvement potential is up to 50%. But in the mid-term this potential will be explored and it is more realistic to assume a somewhat lower **improvement potential of 30%** similar to the previous case study.

2.1.2.8 Case study: Commercial HVAC – integrated control of HVAC requirement of an indoor pool¹⁷⁸

Topic and technological concept

Large amount of energy are consumed annually by HVAC systems of indoor pools.

ICT Application

Siemens building technologies has optimised the energy consumption of the “Brigittenau” indoor pool in Vienna. This technology uses specialised algorithms to calculate the actual ventilation and heating requirements.

Energy Saving Potential

The resulting improvements saved the pool operators over £140,000 a year (approximately 177,500 Euros). The same technology has been applied to optimise energy efficiency in thousands of buildings world-wide, including hospitals, banks, industrial sites and schools. In Germany, Siemens is a contracting partner for over 1600 buildings, and has reported producing savings of almost 650,000 tonnes of CO₂ during the average contract term of ten years. However, it has to be reminded that it is very difficult to generalise savings resulting from HVAC integrated control systems, and to extrapolated average savings to a broader level (e.g. EU level) as these savings are very much dependent on local parameters (e.g. ambient conditions).

¹⁷⁷ Festo product catalogue

[http://a1989.g.akamai.net/f/1989/7101/1d/www3.festo.com/_C1256D56002E7B89.nsf/F92BEF257C027B0CC12572A400434BFC/\\$file/PSI_811_1_en.pdf](http://a1989.g.akamai.net/f/1989/7101/1d/www3.festo.com/_C1256D56002E7B89.nsf/F92BEF257C027B0CC12572A400434BFC/$file/PSI_811_1_en.pdf)

¹⁷⁸ Source : EICTA, High Tech : Low Carbon, The role of the European digital technology industry in tackling climate change, April 2008.

2.1.2.9 Summary of technical trends

In the field of residential and commercial HVAC, ICT-enhanced system monitoring and control is already a common feature. ICT provides for HVAC in general the following functionality:

- Monitoring of conditions (sensor)
- Transmission of sensor data (network)
- Processing, storage and display of data (computer/controller)
- Driving and control of building infrastructure equipment (actuator)

Monitoring: The specific functionality of ICT for HVAC includes integrated or autarkic sensors that can monitor following conditions:

- Outdoor and indoor (external) temperature,
- Burner, boiler, and radiator (internal) temperature,
- Air and fluid circulation, moisture, and particle emissions

Transmission: The sensor data are transmitted over a wired or wireless connection to a controller. The most commonly used technology is an Ethernet type.

Network communication technologies: The first generation of industrial communication was the serial PROFIBUS standard. It differs in two versions. PROFIBUS DP (Decentralised Peripherals), which operates sensors and actuators via a centralized controller with data rates from 9,600 bit/s up to 1 Mbit/s over twisted pair cables or fibre optics, and PROFIBUS PA (Process Automation), which monitor measuring equipment via a process control system in process engineering with a slower data rate of 31.25 kbit/s.

The second generation is industrial Ethernet supporting a higher bandwidth compared to PROFIBUS. Ethernet is a family of frame based computer networking technologies for local area networks (LAN). It is defined in the standard IEEE 802.3 and supports bandwidth from 10 Mbit/s over 100 Mbit/s (fast Ethernet) and 1 Gbit/s (Gigabit Ethernet) up to 10 Gbit/s. In recent years, Wi-Fi, the wireless LAN, was standardized by IEEE 802. IEEE 802.11 is a set of wireless local area network (WLAN).

One type of industrial Ethernet is PROFINET¹⁷⁹. This standard allows data rates up to 100 Mbit/s and is also used in automation systems. PROFINET includes three types of traffic: non real time with a response time of more than 100 ms, real time class 1 with a response time of more than 5 ms and real time class 2 (isochronous real time) with a response time of less than 250 µs.

¹⁷⁹ http://www.ggriller.co.at/images/pdf/metallic/bus_profinet.pdf
http://www.ixxat.com/profinet_intro_en.html

Another type of industrial Ethernet is Modbus¹⁸⁰. It is an Ethernet TCP/IP based simple Client/Server network with transmission rates from 10 Mbit/s up to 1 Gbit/s based on copper cables, fibre optics or wireless standards.

One last type is the deterministic real time protocol Powerlink. Modern implementations reach cycle-times of fewer than 200 μ s and a time-precision of less than 1 μ s since 2006 with transmission rates from 1 Gbit/s.¹⁸¹

It has to be considered that higher data transmission rates come along with higher electricity consumption. For a typical PC this means, if an Ethernet link is operating at 1 Gbit/s instead of 100 Mbit/s, it uses about 2 Watt (AC) more electricity. This 2 W difference can also be measured at the other end of the link at the LAN switch. This energy use does not depend on the traffic on the link. Therefore one proposal to improve the energy efficiency of Ethernet is ALR. ALR stands for adaptive link rate. Ethernet links should change their data rates dynamically in response to traffic levels. For low traffic levels, low transmission rates are sufficient and should be used. Thereby the already existing data rates of 0, 100, 1,000, and 10,000 Mbit/s should be used. If ALR is widely installed in PCs, this would result in considerable energy savings as most Ethernet links – especially PC to LAN switch links – have very low traffic levels most of the time.¹⁸²

According to [GE 2008]¹⁸³ the reliable, robust wireless communication system for industrial monitoring can be realised by the Ethernet-Standard: IEEE 802.15.4. It is a low-cost standard and a type of wireless personal area Network which focuses on low-speed everywhere communication between different devices. The communication range is 10 meters and the transfer rate is 250 kbit/s or even lower.

The challenge in creating a low cost sensor network is a noisy unreliable channel, a short battery life, the life cycle costs, the network security and the gateways. Solutions are a characterised channel and qualified design approach, low duty cycle operation and energy harvesting, minimised device cost and maximised life and reduced installation expense, data encryption, standard interfaces.

Controller: The control unit is processing the sensor data in order to generate an actuator input. The controller usually maintains a customised system configuration

¹⁸⁰ <http://www.anybus.com/technologies/modbusplus.shtml>

¹⁸¹ Mike Bennet, Ken Christensen, Bruce Nordman: *Improving the Energy Efficiency of Ethernet: Adaptive Link Rate Proposal*, ethernet alliance, July 2006, online available at :

http://www.ethernetalliance.org/technology/white_papers/alr_v10.pdf

¹⁸² Mike Bennet, Ken Christensen, Bruce Nordman: *Improving the Energy Efficiency of Ethernet: Adaptive Link Rate Proposal*, ethernet alliance, July 2006, online available at :

http://www.ethernetalliance.org/technology/white_papers/alr_v10.pdf

¹⁸³ Daniel Sexton: *Distributed Wireless Multi-Sensor Technologies*, by GE Global Research prepared for The U.S. Department of Energy; February 19, 2008, online available at:

<http://www.osti.gov/bridge/servlets/purl/926169-WjRGDo/>

(e.g. threshold temperatures) based on user software. The control unit could be a microprocessor or a personal computer. Some systems feature displays for user interaction such as individual system setting. Miniaturization of electronic components enables today the integration of the control unit in the main equipment.

Actuator: ICT-enhanced condition monitoring and control enables demand specific drive of HVAC equipment. Through that functionality it provides following advantages and energy saving potentials to residential and commercial HVAC systems:

- Fast and accurate reaction to changing system conditions (e.g. temperature)
- Automated or remote reaction to changing system conditions
- High quality of service (QoS) and lower failure risk
- Predictive maintenance or maintenance on demand
- Flexibility and system design (e.g. particularly in case wireless sensor/actuator systems)

2.1.2.10 Residential sector energy saving potential of ICT-enhanced HVAC

The ICT related energy savings in the field of HVAC are highly individual and system specific. ICT alone does not save much energy. But in conjunction with new boilers, pumps, heaters, radiators, electric blends and insulation concepts ICT enhances the effectiveness of the whole HVAC system.

It is not reasonable to try to estimate the pure ICT-related energy saving potential in the field of residential or commercial HVAC systems. In order to forecast a realistic energy saving potential we therefore make the following assumptions:

- The energy consumption of buildings and the HVAC in particular is generally fixed by the following technical factors:
 - The physical design of the building (e.g. wall insulation, windows, sun-blinds)
 - The energy sources and supply system (e.g. solar, gas, oil, heat exchanger)¹⁸⁴
 - The permanently installed building equipment (e.g. heaters, boilers, elevators, lighting, telecom)
 - The individual power consumption of end-user devices (e.g. white goods, consumer electronics)
- Despite the constructive and technical parameter of the HVAC system it is the individual utilisation that determines the energy consumption:
 - The individual temperature settings und acceptable conditions

¹⁸⁴ As an example, the "Passive House" concept intends the utilization of natural (renewable) resources in order to reduce the consumption of conventional carbon energy. The PassivHaus Institute in Darmstadt, Germany: <http://www.passiv.de>

- The programmed temperature threshold values for equipment
- The regional and seasonal weather conditions
- The manual or automatic setting
- Although the case studies indicate a system specific energy saving potential of up to 50% it is not possible to translate these examples on the whole scale and generalise the result due to the different building conditions:
 - Age of buildings and status of energy consumption
 - Level of optimization regarding passive and active HVAC system
 - Different financial incentives and possibilities of the residential user (lower) and commercial user (higher) for the improvement

In order to create a business-as-usual impact scenario (BAU) and ecological improved impact scenario (ECO) we pragmatically assume the following energy savings for residential buildings (EU-27 households) until 2020 (see Table 88).

Table 88: Assumption for improvement scenarios (residential HVAC in 2020)

	BAU Scenario	ECO Scenario
Share of buildings being improved until 2020 (in % of EU-27 households) ¹⁸⁵	25%	50%
Improvement potential of high level category (in % of energy saving)	10%	10%
Improvement potential of average level category (in % of energy saving)	30%	30%
Improvement potential of low level category (in % of energy saving)	50%	50%

Based on these assumptions Table 89 shows the respective results for the BAU scenario.

Table 89: BAU scenario for residential HVAC related energy savings in 2020

BAU-Scenario 2020		best case				worst case		
Level of improvement	Regional Scope	Number of households [Mio]	Energy consumption per area [kWh/m²]	Improved energy consumption per area [kWh/m²]	energy consumption per year [Mtoe/a]	Energy consumption per area [kWh/m²]	Improved energy consumption per area [kWh/m²]	energy consumption per year [Mtoe/a]
high	25% of EU-27	54,0	50,0	45,0	21,3	100,0	90,0	42,5
average	55% of EU-27	118,7	100,0	70,0	88,7	250,0	175,0	221,9
low	20% of EU-27	43,2	250,0	125,0	76,3	400,0	200,0	122,1
	Total	215,8			186,3			386,5

¹⁸⁵ The overall increase in EU households until 2020 to 215.8 million has been considered for the scenarios.

The BAU worst case scenario shows an overall improvement by 8.6% (from 423.0 Mtoe in 2020 to 386.5 Mtoe in 2020, see Table 83) and the BAU best case shows a slightly higher overall improvement by 9.1% (from 205.0 Mtoe in 2020 to 186.3 Mtoe in 2020). Against the 2020 forecast by [DG TREN 2008] of about 215.0 Mtoe HVAC related energy consumption (see Table 79) the BAU seems a realistic baseline scenario.

Table 90 shows the respective results for the Eco-scenario.

Table 90: Eco-scenario for residential HVAC related energy savings in 2020

ECO-Scenario 2020			best case			worst case		
Level of improvement	Regional Scope	Number of households [Mio]	Energy consumption per area [kWh/m²]	Improved energy consumption per area [kWh/m²]	energy consumption per year [Mtoe/a]	Energy consumption per area [kWh/m²]	Improved energy consumption per area [kWh/m²]	energy consumption per year [Mtoe/a]
high	25% of EU-27	54,0	50,0	45,0	20,7	100,0	90,0	41,4
average	55% of EU-27	118,7	100,0	70,0	81,6	250,0	175,0	203,9
low	20% of EU-27	43,2	250,0	125,0	65,4	400,0	200,0	104,7
	Total	215,8			167,7			350,0

The Eco worst case scenario shows an overall improvement by 17.3% (from 423.0 Mtoe in 2005 to 350 Mtoe in 2020) and the ECO best case scenario an even higher overall improvement by 18.2% (from 205.0 Mtoe in 2005 to 167.7 Mtoe in 2020).

Depending on the reference value we take, it is justified to assume that ICT-enhanced HVAC system optimization could reduce the annual energy consumption of HVAC in EU-27 residential buildings by 8.0% to 17.0% which correlates to 16 Mtoe to 70 Mtoe respectively.

In conclusion, we assume for residential HVAC systems average annual savings by 15% or about 47 Mtoe by the year 2020. This equals to 67.8 Mt CO₂ eq. emission¹⁸⁶.

It should however be kept in mind that the final saving numbers relate to energy saving potential of ICT-enhanced HVAC and not to the ICT part only, as it is not reasonable to try to estimate the pure ICT-related energy saving potential in the field of residential or commercial HVAC systems.

2.1.2.11 Service sector energy saving potential of ICT-enhanced HVAC

With respect to service sector HVAC the impact assessment is mainly influenced by the assumption that commercial users have better financial opportunities which could result in fast modernization or replacement of suboptimal HVAC systems. Due to missing statistical data we take the pragmatic approach that we allocate certain improvement potentials to parts of the overall energy consumption related to service sector HVAC. The baseline scenario is taken from [DG TREN 2008] statistical forecast.

¹⁸⁶ Using the residential sector carbon intensity indicator (**1.44 t CO₂ eq. per toe**) from DG TREN for the year 2020 available in European Commission Directorate-General for Energy and Transport: European Energy and Transport - Trends to 2030, Update 2007, Belgium 2008.

Table 91: EU-27 service sector energy consumption by use (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Services by use</i>	%	Mtoe	%	Mtoe
HVAC	56,6	82,0	53,0	92,5
Other Heat	22,4	32,5	19,5	34,0
Lighting	3,8	5,5	3,4	6,0
EEE/ICT	17,2	25,0	24,1	42,0
Total	100,0	145,0	100,0	174,5

The assumptions for the improvement scenarios are listed in Table 92 below.

Table 92: Assumption for improvement scenarios (commercial HVAC in 2020)

	BAU Scenario	Eco-Scenario
Improvement of buildings until 2020 (in % of EU-27 service sector buildings)	30%	60%
High improvement assumption (in % of energy saving)	50%	50%
Average improvement assumption (in % of energy saving)	30%	30%

According to these assumptions the resulting figures of the BAU and ECO scenario (see Table 93 below) show a considerable energy saving potential of 9% to 30% between the BAU average and the Eco high or respective 8.3 Mtoe to 27.7 Mtoe.

Table 93: BAU and Eco-scenarios for HVAC energy savings in service sector (2020)

EU Energy Consumption	2020	2020	2020	2020
<i>Services by use</i>	Improvement buildings in %	Improvement energy use in %	Energy Consumption in Mtoe	HVAC total improvement in %
Baseline scenario (HVAC total)	0,0	0,0	92,5	0,0
BAU Scenario Average	30,0	30,0	84,2	9,0
BAU Scenario High	30,0	50,0	78,6	15,0
ECO Scenario Average	60,0	30,0	75,9	18,0
ECO Scenario High	60,0	50,0	64,8	30,0

In conclusion, we could assume for service sector HVAC systems a realistic average annual savings by 20% or about 18.5 Mtoe by the year 2020. This equals 23.7 Mt CO₂ eq. emission¹⁸⁷.

¹⁸⁷ Using the service sector carbon intensity indicator (1.28 t CO₂ eq. per toe) from DG TREN for the year 2020 available in European Commission Directorate-General for Energy and Transport: European Energy and Transport - Trends to 2030, Update 2007, Belgium 2008.

2.1.3. LIGHTING AND SECURITY SYSTEMS

2.1.3.1 Comparative market and energy consumption data for lighting

Lighting accumulates to a considerably large portion of electricity consumption not only in the building infrastructure of the residential and tertiary sector, but also in all other industry sectors including agriculture, manufacturing, and construction.

Energy consumption figures related to the total lighting market are listed in the following Table 94. This table indicates on the one hand the impact of lighting including lamps and lighting systems in the residential, service (public) and industry sector tail. On the other hand it shows the overall impact of lighting including also laser, projection and display devices in the industry and tertiary (service sector).

Table 94: Lighting related energy consumption (2005)

EU total lighting (incl. industry)	EU residential sector (households)	EU service sector (commercial/office)	Source
525.0 TWh/a (25% of world total)	105.0 TWh/a (20% of total lighting)		Photonics21 2006 (World/EU in 2005)
662.5 TWh/a (25% of world total)	132.5 TWh/a (20% of total lighting)		OSRAM 2006 (World/EU in 2005)
242.5 TWh/a (25% of world total incandescent lamps)	148.0 TWh/a (61% residential)	94.0 TWh/a (39% tertiary sector)	OECD/IEA 2006 (World/EU in 2005)
	85.0 TWh/a (12.1% of household)	175 TWh/a	JRC 2006 (EU-15 in 2004)
	96.7 TWh/a (12.1% of residential with 799.2 TWh total)		EUROSTAT 2007 (EU-27 in 2005)
		26 TWh/a (office lighting only)	Lot 8 EuP 2007 (EU-25 in 2005)
	Approx. 100 TWh/a (first estimate)		Lot 18 EuP 2008 (EU-27 in 2007)

In order to show the improvement potential later on we need a baseline scenario for the residential and service sector.

We again refer to the most updated statistical data from [DG TREN 2008] which are shown for the residential sector in Table 95 below.

Table 95: EU-27 residential lighting energy (baseline scenario 2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Residential by use</i>	%	Mtoe	%	Mtoe
HVAC	66,0	202,6	64,0	215,0
Water heating / cooking	22,0	67,5	21,4	72,0
Lighting	4,5	13,8	4,5	15,0
EEE/ICT	7,5	23,0	10,1	34,0
Total	100,0	307,0	100,0	336,0

The figure provided by [DG TREN 2008] for residential lighting in 2005 is 13.8 Mtoe. This figure equals an annual electricity consumption of 160.5 TWh¹⁸⁸. In comparison to the figures deriving from other source and the most common assumption that annual electricity consumption related to residential lighting is about 100 TWh the resulting figure from [DG TREN 2008] is quite high. But this higher assumption also indicates the trend that the impact of lighting was somewhat underestimated in the past.

Regarding the tertiary or service sector which comprises the office or commercial use the following data derive from [DG TREN 2008].

Table 96: EU-27 service sector lighting energy (baseline scenario 2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Services by use</i>	%	Mtoe	%	Mtoe
HVAC	56,6	82,0	53,0	92,5
Other Heat	22,4	32,5	19,5	34,0
Lighting	3,8	5,5	3,4	6,0
EEE/ICT	17,2	25,0	24,1	42,0
Total	100,0	145,0	100,0	174,5

The figure provided by [DG TREN 2008] for service sector lighting in 2005 is 5.5 Mtoe. This figure equals an annual electricity consumption of 64.0 TWh. In comparison to the figures deriving from other source such as [EuP Lot 8] and [OECD/IEA 2006] this figure from [DG TREN 2008] seems to be a quite realistic estimate.

For residential sector baseline scenario in this study we use following assumptions:

- Residential sector lighting related energy consumption 160 TWh in 2005
- Residential sector lighting related energy consumption 174.5 TWh in 2020.

For service sector baseline scenario in this study we use following assumptions:

- Service sector lighting related energy consumption 64.0 TWh in 2005
- Service sector lighting related energy consumption 69.8 TWh in 2020

¹⁸⁸ For lighting, all energy is assumed to be electricity, so the conversion factor 11.63 from Mtoe to TWh can be used.

2.1.3.2 Technical status and trends

It is also generally understood that there is a good technical improvement potential in the field of lighting. The reduction of energy consumption related to lighting follows two main approaches:

- New light sources
- ICT-enhanced lighting control

The technical development in these two fields and the application ICT-enhanced solutions are shortly outlined in the following.

2.1.3.3 New light sources

The technical development of light sources is driven by the improvement of the luminescence efficiency, the quality of light, the life span, and of course the price of the lamp. Nowadays the power consumption and overall life cycle efficiency is of concern. Photonics21 provides a pragmatic structure for the evolution of light sources:

- Incandescent lamp (19th century): Conventional light bulbs are still commonly used lamps in Europe with an approximate market share in 2004 of 40% (Philips Lighting). The luminescence efficiency of these lamps is with 12-15 lm/W rather low while power consumption is rather high. The life span of light bulbs is 1,000 hours. But the main aspect is the very low price.¹⁸⁹
- Gas discharge lamp (20th century): Compact florescent lamps use an electronic converter/inverter circuitry for charging the lamp. Advanced electronic components have improved the electrical efficiency and miniaturised the lamp system. The luminescence efficiency is with 60-100 lm/W high while power consumption is rather low (1/4 to 1/5 of conventional light bulb). The life span of light bulbs is with 10,000 hours long. The critical point is the light quality and the considerably higher price.¹⁹⁰
- Solid state lamp (21st century): Inorganic and organic light emitting diodes (LED/OLED) are quite new light systems which are considered the next generation of low power light source. As today's white LED reach efficacies up to 40-110 lm/W (efficiency depends on colour temperature and colour rendering), they are more and more used in general lighting. The power consumption is very low in mW range. LEDs are considered to have the best market potential due to an inexpensive mass production.¹⁹¹

¹⁸⁹ OECD/IEA 2006

¹⁹⁰ OECD/IEA 2006

¹⁹¹ OSRAM History of LED

http://www.osram.com/osram_com/Professionals/Opto_Semiconductors_&_LED/Everything_about_LED85033/Hist_ory_of_LED/index.html

Ban of Incandescent lamps: On March 9, 2007, the European Union announced its own intentions to eliminate today's general service incandescent lamps starting 2009 in order to significantly reduce carbon emissions. The EuP Preparatory Study on residential lighting Lot 19 has to be monitored in that respect, because it seems to provide the scientific background for the intended ban. A ban of conventional light bulbs is already in place in Australia. With the Energy Independence and Security Act of 2007 becoming law, the United States have joined Canada, Europe and Australia in developing new lighting efficiency standards targeting today's inefficient version of the incandescent light bulb. Accordingly general-service bulbs begin to be eliminated in 2012 in the USA.

2.1.3.4 Case study: Inorganic and Organic LED based lighting

Topic and technological concept

The solid state lighting technology is directly linked to ICT. LED based lighting is in most cases not a single lamp solution but a system design with a large number of (individually) controllable light sources (LEDs). Lighting with LEDs incorporates complex technologies for light mixing (true colour rendering), thermal management (active heat dissipation), reliability and long-term stability. Despite these challenges the LED technology has a great potential to reduce energy consumption.

ICT Application

The following examples for (O)LED lighting are providing an overview on the state-of-the-art. It is difficult to say if inorganic and organic LED lighting is considered ICT. From a technology point of view (circuitry design, materials, manufacturing processes, etc.) it seems reasonable to consider LED lighting an ICT. Solid state lighting is also directly linked to advanced display technology such as large outdoor displays based on LEDs.

Seoul Semiconductor, one of the world's leading LED manufacturers, developed Acriche, the first semiconductor lighting source that can be driven directly from an AC outlet (power systems ranging from 100–120 volts and 220-230 volts) without a converter. Acriche has with 35,000 to 50,000 hours a comparably longer working life¹⁹². Acriche is applicable for general lighting, architectural lighting, street lighting, residential lighting (Under-cabinet), decoration lighting and sing lighting. For example, the Acriche 3.3 W LED system develops 200 lm, which equals 60 lm/W. Further development aims on 80 lm/W for 250 lm packages.¹⁹³

Osram Opto Semiconductors developed the LED lighting system Golden Dragon Oval for street lighting. Only 12 LEDs are necessary for illuminating a street from a height of 3.4 meter. The Golden Dragon Oval LED lighting source can be driven directly with 220-230 volts and without a converter. The system develops 60 lm at 359 mA and is usually

¹⁹² Regular light bulb has a working time of 1.000 hours.

¹⁹³ <http://www.acriche.com/en/>

driven at 130 mA. They consume 0.35 W per LED (1 W in street lighting standard application).

Similar results have been achieved with the Golden Dragon LED system for residential lighting. The replacement of a 100 W light bulb with a LED system reduced energy consumption by 82% or 34 kg CO₂.

OLEDs are organic light-emitting diodes whose electroluminescent layer is composed of a film of organic compounds. They can be used in displays for e.g. TVs and cell phones but also for lighting applications. State-of-the-art for OLED is 10-30 lm/W¹⁹⁴, but that is a “short-time frontier” as there are several projects to improve that like the EU-project OLLA (high brightness Organic LEDs for ICT & next generation Lighting Applications) which aims to develop large-scale, white OLED tiles with a lifetime of more than 10,000 h and an efficiency of 50 lm/W for lighting purposes¹⁹⁵.

OLEDs are flat light sources and could be used in light systems with controllable colour and, in future, can be made on flexible substrates. Important R&D topics with respect to OLEDs are the search for more stable, higher efficiency organic semiconductors. The power efficiency of OLEDs should be improved through doping technologies which improve the electrical conductivity of the OLED transport layers. The doping material needs to be robust enough to resist cross contamination in a vacuum deposition process and does not diffuse within the OLED over time which would reduce the light generation efficiency of the OLED¹⁹⁶.

Rollex is a project funded by the German Federal Ministry of Education and Research and stands for “roll-to-roll production of high efficient light-emitting diodes on flexible substrates”. With the roll-to-roll-concept, noticeable lower coating costs are expected compared to cluster or inline concepts used for display production. The use of e.g. low-priced aluminium foils as substrate for the deposition of very efficient organic light-emitting diodes is planned as a further cost reducing step. Aim of the project is to develop a pilot plant¹⁹⁷.

Energy Saving Potential

According to Photonics21, OLEDs bear the technological potential to achieve unprecedented efficiencies in energy to light conversion. Despite material issues, system design has to be addressed in order to improve light generation process, light propagation as well as the thermal management for OLED devices beyond the 50 lm/W boundary. Inorganic and organic LED based lighting systems have the potential to

¹⁹⁴ NanoMarkets: *Emerging Markets for Printed and OLED Lighting*, Market Research Report, July 2007

¹⁹⁵ Fraunhofer Magazin: *Leuchtende Zukunft*, Interview with Prof. Karl Leo, 4/2007 and OLLA website: <http://www.hitech-projects.com/euprojects/olla/index.html>

¹⁹⁶ Philips Research Password 24: *European collaboration promises a bright future*, September 2005

¹⁹⁷ Novaled: http://www.novaled.com/news/2007_03_07_pr.html

reduce energy consumption by 50% in comparison to fluorescent lamps and up to 85% in comparison to incandescent lamps.

2.1.3.5 ICT-enhanced lighting control

Whereas the industry in Europe according to the European Lamp Companies Federation (ELC) sees considerable barriers for the change towards new lamp systems and respective lighting control, the situation in the USA seems more promising. Lighting automation is now becoming the rule rather than the exception, according to an U.S. market research study funded by Ducker Research in 2003.¹⁹⁸ The study found that lighting automation is being used in a majority of new construction and renovation projects in the office and school markets. Approximately 65% of these projects feature lighting automation. This U.S. study also found that users are very interested in the advantages of controls – primarily energy savings and energy code compliance – but seek simple, low-cost solutions.

Lighting can be turned on and off as well as dimmed most efficiently with a lighting control that is integrated in the building automation system (BAS). Lighting controls are devices that regulate the operation of the lighting system in response to an external signal (manual contact, occupancy, timer, light level). Lighting control is scalable from a localised manual switch up to lighting controls that are integrated in a building automation system (BAS). ICT-enhanced lighting control systems include:

- Occupancy or motion sensors linked to a control panel
- Daylight or ambient light sensor linked to a control panel
- Timer-based lighting control

Most desirable lighting automation technology includes standard protocols along with plug-and-play solutions and low-cost electronic dimming ballasts. Advanced controls and dimming ballasts are fields where ICT has a potential for improvement. ICT is linking the sensors with the control panels and actuators. It is the technical interface in an integrated building automation system (BAS). ICT is also providing software controlled data processing, memory and display functionality for easy user interaction. Visualisation is a keyword in that respect. The wireless communication option is increasing the flexibility (cost effectiveness) for modernising or upgrading the lighting system.

2.1.3.6 Case study: Occupancy and daylight sensors

Topic and technological concept

¹⁹⁸ <http://www.aboutlightingcontrols.org/education/papers/trends.shtml>

Occupancy sensors automatically turn the light on and off when people enter or exit a restroom, a classroom, a conference room, a hallway, or an office. According to lighting industry, using occupancy sensors can eliminate 20 – 80% of lighting energy costs.

The daylight sensor continuously updates the illumination level in accordance with the increasing or decreasing daylight. With this readjustment of the light intensity to for instance constant 600 lx, energy savings up to 75% are possible.

ICT Application

More detailed information about occupancy sensors and daylight detecting systems gives “The Green Light Programme”.¹⁹⁹ This Program encourages “non-residential electricity consumers (public and private) [...] to commit towards the European Commission to install energy-efficient lighting technologies in their facilities when it is profitable, and lighting quality is maintained or improved”. According to this project, there are mainly three different types of occupancy detectors:

- *Passive infrared (PIR) occupancy sensors:* These sensors respond to the motion of infrared energy (or heat) produced by human bodies. They use one or more pyro-electric detectors located behind an infrared-transmitting, segmented lens. The detector’s field of view is typically divided into detection zones. Lights are turned on when the sensor detects the motion of a heat source across a detection zone boundary within a defined period. Passive infrared sensors are “line-of-sight” devices that need an unobstructed view of motion to operate effectively.
- *Ultrasonic occupancy sensors:* These systems operate by responding to the change in reflected sound waves in a space caused by moving objects. Ultrasonic sensors operate at frequencies that are above human sensitivity (20 kHz), typical operating frequencies are 25, 30 and 40 kHz. Compared to infrared sensors they detect smaller motions and do not require a direct line-of sight.
- *Ultrasonic-infrared occupancy sensors:* These detectors combine passive infrared and ultrasonic technologies and are therefore also called “dual” or “hybrid” sensors. The light is kept on as long as the on of the technologies detects motion. Thereby, the problem of turned off lights while the space is occupied is reduced.

Most common daylight detectors fall into three categories:

- *On/Off systems:* When the sensor detects too much or too less daylight, lights are switched off or on. This causes sudden and noticeable changes in the lighting level and can lead to occupant complaints. For areas which are well “day lit” and the switching frequency is low, these types of systems can be applied.

¹⁹⁹ <http://www.eu-greenlight.org/>

- *Stepping systems:* These systems are very similar to the on/off-systems but have one or more intermediate lighting positions between the on and off positions.
- *Dimming systems:* They ensure that the sum of daylight and electric lighting always reaches the design level by sensing the total light in the controlled area and adjusting the output of the electric lighting to top-up the daylight as necessary. If daylight alone reaches the design level the electric lighting is dimmed to extinction. Unlike photoelectric switching, photoelectric dimming control is relatively unobtrusive. The energy saving potential of dimming control is greater than for simple photoelectric switching and the mode of control is more likely to be acceptable to the occupants. The developments in electronic ballasts have facilitated the use of photoelectric dimming systems for fluorescent lighting, particularly in commercial interiors.

Whether or not a daylight responsive lighting control system is suitable depends on the daylight availability within the room. The most appropriate applications are of course in spaces with much daylight.²⁰⁰

For all sorts of detectors it is important to install a time delay, since there may be still persons in the room which remain still and quiet for some time. The different types of detectors differ in the degree of sensitivity. It can also be differentiated between “off-only systems” which switch the light off when no occupancy is detected and systems which also switch the light back on. The latter is more commonly used.

Energy Saving Potential

The energy savings achieved by occupancy detectors vary depending on occupancy pattern and of the size of the covered area. Typically, energy savings of 35-45% can be achieved.²⁰¹

Appropriate lighting controls can yield substantial cost effective savings in energy used for lighting. Lighting energy consumption in offices can typically be reduced by 30% to 50%. Simple payback can often be achieved in 2 to 3 years.

2.1.3.7 Summary of technical trends

The energy efficiency in lighting systems is driven by two developments:

- new light sources particular solid state (LED)
- advanced lighting automation

²⁰⁰ The Green Light Programme

http://www.eu-greenlight.org/What-to-do/Choose-Options/Control-System/c_daylight.htm

²⁰¹ The Green light Programme

http://www.eu-greenlight.org/What-to-do/Choose-Options/Control-System/c_occupancy.htm

It is interesting to notice that ICT is not only used for a demand management and control of infrastructure components but also becomes an integrated part of the solution. The shift towards LED lighting systems is technologically closely linked to ICT (similar semiconductor manufacturing processes) with an enormous energy saving potential. LEDs use as little as one-seventh the energy as an incandescent light bulb and can last about 100 times longer.

The problems with LEDs are to some extent still the long-term stability and the thermal management. From manufacturing point of view the electronic packaging (micro-system integration technology) is more complex. But it is expected that the resource efficacy and production yield will increase quickly when mass manufacturing is established. This trend is ongoing.

2.1.3.8 Energy saving potential of ICT-enhanced lighting

As for HVAC systems also for lighting, the resulting energy savings are highly individual and system specific. It depends on the already used light source (incandescent lamps, fluorescent lamps) the degree of automation (simple light control /timer controlled lighting already standard in commercial buildings) and the individual behaviour.

According to a presentation of Gerald Strickland, Secretary General European Lamp Companies Federation (ELC), at the European Union Sustainable Energy Week on 30th January 2008 is energy efficient lighting one of the quickest, most practical and most cost effective ways for Europe to save energy.²⁰² He states that according to our industry estimates, we could save Europe approximately 42.5 Million tons of CO₂ through energy efficient lighting each year (conservative estimates!). More than 75% of office lighting systems still inefficient and the current switch over rate is 7% per year because the average lifetime of lighting installation is 25 years. Approximately 85% of lamps currently in EU homes are energy inefficient.

Because of the huge differences in efficiency between old and new systems is the energy saving potential 30 to 80%.

²⁰² Gerald Strickland of European Lamp Companies Federation at the EUSEW 2008:
http://www.elcfed.org/uploads/documents/Gerald_Strickland-Energy_efficiency_Eu_Lighting_Industry.pdf

Table 97: Saving potential for lighting according to ELC 2008²⁰³

	Savings potential (per year) *			
	CO2 (Million tonnes)	Savings potential (KWh) = 0.37 kg CO2/kWh (**)	Savings potential in Euro (***)	Euro/kWh (***)
Domestic Lighting	23	62.2	€ 9.3 billion	€ 0.15
Office Lighting	8	21.6	€ 2.2 billion	€ 0.10
Industrial Lighting	8	21.6	€ 2.2 billion	€ 0.10
Street Lighting	3.5	9.5	€ 0.9 billion	€ 0.10
Total	42.5	114.9	€ 14.6 billion	N/A

* This figure is based on the latest (conservative) industry estimates for the a total switch to energy efficient street, office, industry and domestic lighting in the EU (27). Detailed savings potential figures from each EU member states are in the process of being calculated by the ROMS programme.
 ** Figure courtesy of the International Energy Agency - 0.37kg CO2/kWh - CO2 EMISSIONS FROM FUEL COMBUSTION (2006 Edition) - II. 61
 *** Figure courtesy of Philips Lighting B.V

The case studies and public statement of industry representative indicate that the assumption of an **average energy improvement potential of 30% to 50%** is justified. System solutions may generate energy savings of up to 70-80% due to the combination of advanced light sources and sophisticated light control systems²⁰⁴. Regarding the average trend we have to conclude that there is again a slight difference in the improvement potential between the residential (private) and service (commercial) sector due to different financial opportunities. This consideration is reflected in the business-as-usual (BAU) scenario and ecological (Eco) scenario for the residential and service sector. The improvement potential for the residential sector is somewhat smaller than in the service sector. That means that the service sector will improve faster to a higher level of energy efficiency. Nevertheless we consider for both sectors a quite high improvement potential, which seems realistic against the current technical and legislative situation. The main assumptions for the scenarios are shown in following Table 98.

²⁰³ Gerald Strickland: *Energy efficiency in the European Lighting Industry*, European Lamps Company Federation (ELC), January 2008

²⁰⁴ A case study reported in EICTA report: the replacement of UK National Theatre's lighting (outdoor) could reduce energy consumption by 70% (source: EICTA High tech: Low Carbon, April 2008)

Table 98: Assumptions for lighting improvement scenarios

	BAU Scenario	ECO Scenario
Share of total lighting until 2020 which is assumed to be improved (in % of EU-27 residential and service sector)	50%	75%
Improvement potential of energy consumption (in %)	30%	50%

The results of the scenarios are shown the Table 99 below. According to our scenario the **overall energy savings are between 15.0% and 37.0% in both sectors**. In terms of electricity consumption the **residential scenarios indicate an annual saving of 25.6 TWh to 65.2 TWh (11.7 to 29.9 Mio t CO₂ emission eq) in 2020 and the service sector scenario 16.3 TWh to 31.4 TWh (7.5 to 14.4 Mio t CO₂ emission eq).**

Table 99: BAU and Eco scenarios for residential and service sector lighting

EU Energy Consumption	2020	2020	2020	2020	2020	2020
Lighting	Improvement total lighting in %	Improvement energy use in %	Energy Consumption in Mtoe	Lighting total savings in %	Energy Consumption in TWh	Lighting total savings in TWh
Residential lighting (baseline)	0,0	0,0	15,0	0,0	174,5	0,0
BAU Scenario (average)	50,0	30,0	12,8	15,0	148,9	25,6
Eco Scenario (high)	75,0	50,0	9,4	37,3	109,3	65,2
Service sector lighting (base)	0,0	0,0	6,0	0,0	75,6	0,0
BAU Scenario (average)	50,0	30,0	5,1	15,0	59,3	16,3
ECO Scenario (high)	75,0	50,0	3,8	36,7	44,2	31,4

In conclusion, we assume as a realistic figure 30% energy savings for the residential sector. This average annual energy savings related to advanced light sources (LED) and ICT-enhanced lighting control are an estimated 4.5 Mtoe which equals 52.3 TWh or 24.0 Mt CO₂ emission eq²⁰⁵.

For the service sector, we assume an average of 25% annual savings which equals an estimated 1.5 Mtoe, 17.5 TWh or 8.0 Mt CO₂ emission eq.

It is difficult to quantify the exact energy savings resulting from ICT-enhanced lighting control alone, as system adjustments which aim on energy efficiency usually include the substitution of inefficient light sources as well. The above mentioned case study on occupancy and daylight sensors indicated that through efficient light control savings of 35 to 45% are possible. According to these numbers, it seems feasible that the average BAU-Scenario (improvement by 30%) is representative for the real life energy savings through advanced ICT light control.

²⁰⁵ This was calculated based on the CO₂ emission factor from the EuP EcoReport Tool developed in the framework of the EuP Directive 2005/32/EC where **1000 kWh (Electricity)= 458.214 kg CO₂ eq**. This factor was used throughout the period under review (2005-2020). For the conversion from Mtoe to TWh (when energy is electricity) the factor 11.63 was used.

2.1.4. OTHER ELECTRICAL AND ELECTRONIC EQUIPMENT IN BUILDINGS

2.1.4.1 Comparative market and energy consumption data

The category comprises of a broad range of electrical and electronic equipment (EEE) in buildings including:

- Building equipment with large electrical drivers (e.g. elevators, escalators, automatic gates, lifting ramps)
- Building security and safety automation (e.g. fire/smoke alarm systems, security looks and intruder/motion detectors, surveillance cameras)
- White goods (e.g. refrigerators, freezer, washing machines, stoves, ovens)
- Information and communication equipment (e.g. ICT devices covered in Task 1)

Basic data on energy consumption of EEE in the residential and service sector derive again from [DG TREN 2008] and are shown in Table 101 and Table 100.

Table 100: EU-27 residential energy consumption by use (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Residential by use</i>	%	Mtoe	%	Mtoe
HVAC	66,0	202,6	64,0	215,0
Water heating / cooking	22,0	67,5	21,4	72,0
Lighting	4,5	13,8	4,5	15,0
EEE /ICT	7,5	23,0	10,1	34,0
Total	100,0	307,0	100,0	336,0

Table 101: EU-27 service sector energy consumption by use (2005 and 2020)

EU Energy Consumption	2005	2005	2020	2020
<i>Services by use</i>	%	Mtoe	%	Mtoe
HVAC	56,6	82,0	53,0	92,5
Other Heat	22,4	32,5	19,5	34,0
Lighting	3,8	5,5	3,4	6,0
EEE/ICT	17,2	25,0	24,1	42,0
Total	100,0	145,0	100,0	174,5

In 2005 the EEE and ICT in the residential sector accounted for about 23.0 Mtoe and in the service sector 25.0 Mtoe. The 2020 forecast indicates a considerable increase in energy consumption to 34.0 Mtoe (residential) and 42.0 Mtoe (service) which is related to the growing utilisation of ICT equipment. The energy consumption for EEE and ICT is generally electricity (fuel or solar powered back-up power supplies are not considered).

The year 2005 energy EEE/ICT figures from [DG TREN 2008] equal 267.5 TWh (residential) and 290.8 TWh (services sector). In order to confirm the magnitude of these figures we made an own calculation based on the electricity consumption of households of 799.2 TWh [EuroStat 2007] and the break-down per use by [JRC 2006]. According to this calculation the electricity consumption of EEE/ICT amounts 357.2 TWh (see Table 102). This is a considerably higher – but from the data more

realistic – electricity consumption allocated to EEE/ICT. Nevertheless the difference shows the uncertainty of some statistical data and the growing need for more accurate statistics.

Table 102: EU-27 residential energy consumption by use according to EuroStat 2007 and JRC 2006

EU Electricity Consumption	2005	2005
Residential by use	%	TWh
HVAC	26,6	212,6
Water heating / cooking	16,6	132,7
Lighting	12,1	96,7
EEE/ICT	44,7	357,2
Total	100,0	799,2

The EU-25 stock and electricity consumption of white goods in 2005:

- Refrigerators (181.637 Mio units) and freezers (81.128 Mio units) consume together annually 106.03 TWh according to [ENEA/ISIS, Lot 13, Task 2].
- Washing machines (167.333 Mio units) consume annually 51.27 TWh according to [ISIS, Lot 14, Task 2].
- Dishwashers (68.608 Mio units) consumed consume annually 18.56 TWh according to [ISIS, Lot 14, Task 2].

This totals in an **electricity consumption for white goods in 2005 of 175.86 TWh/a.**

Data on the stock of elevators and escalators in the EU could not be obtained. In order to have a reference data set we refer to the situation in the USA. According to Sachs (2005)²⁰⁶, there are between 700,000 and 800,000 elevators in the United States. According to an article by elevator-world.com on “New Technologies Provide Options for Making Escalators More Energy Efficient”, approximately 355,000 escalators were in operation worldwide in 2005 [Hurst 2007]. It is feasible to assume that approximately 25% of world total is situated in the EU. The number of escalators would range between 80.000 and 100.000 units accordingly. The typical energy consumption related to escalators is unknown.

According to [Sachs 2005] elevators and escalators consume typically 3% to 5% of the energy in modern buildings. If we sum up the 2005 residential and service sector energy consumption (452 Mtoe) and assume that elevators and escalators are located in 1/3 of all buildings (150 Mtoe) and consume an average 4% of total building energy then the resulting energy consumption would be 7.5 Mtoe or 87.2 TWh, which is a considerable amount of energy.

This totals in an **electricity consumption for elevators and escalators in 2005 of 87.2 TWh/a.**

²⁰⁶ Harvey M. Sachs: *Opportunities for Elevator Energy Efficiency Improvements*, American Council for Energy-Efficient Economy, April 2005. http://www.aceee.org/buildings/com1_equp/elevators.pdf

2.1.4.2 Elevators and escalators

Elevators typically use 3% to 5% of the energy in modern buildings (Sachs 2005). The energy consumption can differ over a wide range depending on the number of starts / door openings per year and the drive mechanism. Standby consumption can go up to 2 kW/lift, which would result in 10 MWh/a for an elevator which is on 5,000 h/a.

With respect to **elevators** ICT finds application most commonly for maintenance and security measures in case of breakdowns. ThyssenKrupp²⁰⁷ provides an innovative service feature for control systems, VISTA Remote Monitoring, which monitors the performance of the elevators around the clock. The system will alert if something out of ordinary occurs or if the elevator's performance does not achieve optimum standards. A communication device, installed inside the elevator controller, relays an ongoing stream of information to a call centre. Critical events are immediately forwarded to the local office where appropriate action can be taken.

Hitachi²⁰⁸ developed a remote monitoring system which detects warning signs and responds before the systems actually breaks down. Invented for helping elderly or persons with a handicap, there is also a software programme installed that reads information out loud from a computer screen.

As these examples indicate, advanced monitoring systems enable a more effective resource allocation which can save energy. This means for instance that a service team can be scheduled according to specific maintenance demand rather than on duration based servicing plan. This can save energy because it may reduce the frequency of service tours. For case studies see sections 2.2.3.3 and 2.2.2.4.

With respect to **escalators**, Hitachi Ltd. of Japan started selling its VX Series of escalators on January 21, 2008, which features advanced functions designed for improved safety and energy savings so as to be better for both riders and the environment.

The standard model can operate in "eco-mode," reducing power consumption by about 13 percent by detecting the rider load based on information from the inverter controls. The escalator reduces its operational speed imperceptibly to riders. The new model also has a variety of new optional functions for energy saving not available in conventional models. These options include an automatic start system, which starts operation when a rider approaches the escalator, and a "crawl" mode that runs the escalator at a speed of ten meters per minute when there are no riders.

²⁰⁷ ThyssenKrupp: www.thyssenkruppelevator.com/vistaRemote.asp

²⁰⁸ Hitachi: www.hitachi.com/csr/csr_images/khoukoku2007.pdf

2.1.4.3 Security systems

Security systems are a minor contributor to the overall energy consumption in buildings. However, security systems such as smoke detectors and fire alarm systems, monitoring cameras, automatic doors and windows, as well as bell and intercom systems are important features of buildings with high requirements on reliability and accuracy.

Security systems are usually highly integrated into the building infrastructure. The application of ICT is related to sensors, monitoring and control systems. The miniaturisation and digitalisation of electronic components and ICT are impacting the performance, size and energy consumption of sensors, scanners, locks, cameras, and displays. In the field of building automation and security system is ICT a main driver of innovation.

It was not possible to obtain quantitative data neither on the energy consumption related to security systems in the EU nor the respective energy saving potential in conjunction with ICT applications.

2.1.4.4 White goods

Electrical appliances such as refrigerators, freezers, washing machines, dryers, dish washer, electric stoves, microwave ovens and smaller electric cooking appliance are a source of constant or frequent power draw. Large electrical appliances feature rated power consumption between 500 and 3,500 Watts. The current EuP Preparatory Studies provide again the most updated data on energy consumption related to this product category. The application of ICT in support of the functionality of large and small household appliances was also a topic in these studies. However, ICT applications have been acknowledged for these products mostly in terms of information support and less in direct energy efficiency. Nevertheless, sensor-based electronic power conversion, drive controls and switches are an integrated technology already for some time due to the growing energy efficiency requirements as a result of the implemented EU Energy Label.

For newer models, mainly in high price range, the feature “network connectivity, the communication between household appliances” becomes available. Especially for refrigerators and freezers this feature is increasingly offered. It should e.g. allow in combination with RFID on food products an online check which products are inside the device, let the device produce the shopping list or inform the user when certain items are going to expire.

At the moment such a feature for refrigerators, freezers and dishwashers is evaluated with a very low priority by the users (user survey). But, according to a manufacturer

questionnaire done within Lot 13 and 14²⁰⁹, the importance of this feature will increase in the users' priority. Also for washing machines the importance of such a feature will increase, but on a much lower level. At the moment this feature has the lowest priority for the user. Features like "timer, delay start" and displays to show the remaining time of the washing cycle are more important for washing machines. [ENEA/ISIS, Lot 13, Lot 14]

At the moment energy savings for white goods through the application of ICT can't be quantified. These products became already a lot more efficient in the last years. It is questionable, if networked devices would lead to further reductions in the energy consumption. Instead it seems very likely that it would result in increased energy consumption due to additional devices (e.g. additional PCs or always on PCs).

2.1.5. SYSTEMATISATION OF THE IDENTIFIED TECHNICAL TRENDS

ICT is usually the "final element" to an effective system such as a low energy building. The extended monitoring and networking capability which ICT provides is linking the architectural and environmental conditions of a building infrastructure with its main installations and respective HVAC, lighting, security systems, and large electrical equipment. ICT in this sense of a "networked sensors/control/actuator system" makes the building infrastructure "smart".

ICT offers following principle functionality:

- Monitoring of conditions (sensor)
- Transmission of sensor data (network)
- Processing, storage and display of data (software-based control)
- Actuating in response to the controllers command (actuator)

The first aspect of how ICT can improve energy efficiency of buildings is **connectivity**. ICT links single elements in the building infrastructure and enables an automatic reaction to changing conditions. This capability allows a better energy utilisation or energy on-demand within a given building infrastructure.

The second aspect of how ICT can improve energy efficiency of buildings is **flexibility**. ICT enables an effective retrofitting or modification of individual equipment in the existing building infrastructure. This allows installing energy saving equipment in short cycles without a complete system replacement.

The third aspect of how ICT can improve energy efficiency of buildings is **transparency**. ICT provides through sensor data useful information to the system administrator or user. This information helps to analyse further energy saving potentials and could

²⁰⁹ EuP preparatory studies on lot 13 and 14 related to domestic refrigerators and freezers and domestic dishwashers and washing machines (www.ecocold-domestic.org and www.ecowet-domestic.org)

result in adjustment of the operation parameter. The sensor data are also used for detecting suboptimal operations or maintenance demand. Energy saving is in this case related to more optimised servicing and the avoidance of system breakdowns.

The fourth aspect of how ICT can improve energy efficiency of buildings is **ambient intelligence**. ICT provides the vision of a technology that will become invisibly embedded in our natural surroundings (building infrastructure), present whenever we need it (during emergencies), enabled by simple and effortless interactions, adaptive to users and context-sensitive, and autonomous.²¹⁰

The last aspect of how ICT can improve energy efficiency of buildings is **miniaturisation**. The technical performance of ICT is related to miniaturisation in the field of semiconductor technologies (active electronic components) and optoelectronic technologies (passive electronic components and photonics). ICT develops into micro-systems. The small size allows the easy embedding of ICT into almost any equipment. It also allows the recruitment of new types of energy for running the ICT system. Autarkic power supply through the use of ambient energy sources (e.g. vibration, changes in temperature or electromagnetic field) is a key concept in that respect. A small but interesting energy saving potential derives from an autonomous operation of single ICT components such as autarkic operating temperature or smoke sensors.

2.1.6. QUALITATIVE AND QUANTITATIVE ENERGY SAVING POTENTIAL

2.1.6.1 Summary of quantitative assessment

In this task we should assess the EU energy saving potential of ICT applications in buildings. As a matter of fact a quantitative assessment is difficult and had to be made based on various assumptions. In order to create justified impact scenarios we had to parameterise the influencing factors. This was done by a qualitative assessment.

As already indicated before, it is justified to say that ICT is the “final element” in a low energy building. The study has shown that the existing diversity of buildings (e.g. size, age, level of modernisation, utility supply concept, age and efficiency of installed building infrastructure equipment) in conjunction with the regional and local conditions leads to a very heterogeneous level of energy efficiency. Because the buildings are on different “improvement levels” it was possible to assess the impact of ICT applications only with a rough estimate. The building’s energy consumption has to be seen as system of following aspects:

- The buildings location (e.g. in the cold north or warm south, next to a shady tree or in the open)
- The buildings architecture (e.g. the wall and roof insulation, window setting and size, shades and blends)

²¹⁰ W. Weber, J. M. Rabaey, E. Aarts (2005): *Ambient Intelligence*, Springer Berlin, Germany.

- The buildings heating, water, and power supply concept (e.g. district heating and power supply or autarkic co-generating systems using renewable resources such as solar thermal energy)
- The power consumption and automation level of the building's utility equipment (e.g. age of a boiler, radiator etc.)
- The individual use (e.g. some persons likes it warm and light others not)
- Most important is however to know the existing level of energy efficiency (e.g. for HVAC there have been assumptions for differences by region).

For a quantitative assessment of the energy saving potential we first refer to a Baseline-Scenario which was given by the [DG TREN 2008] statistical data on energy consumption for 2005 and 2020. All impact scenarios would match the calculated energy savings against this fixed value. Secondly we always assumed that not the whole market (e.g. stock or value of energy consumption) would be subject to improvement but only parts of it. This consideration derives from the notion that there are different financial opportunities e.g. between private (residential) and commercial (services) user of buildings. Third consideration is that there are different levels of improvement as well. These levels are determined by the system characteristics or complexity of interacting equipment or factors (e.g. electrical power, heat, cooling, ventilation, moist). In reality the complexity of this matrix is very high. But through pragmatic assumption we can roughly estimate the magnitude of an improvement potential.

To calculate the overall energy savings in buildings the scenario for HVAC and lighting are combined.

For the Baseline-Scenario, BAU- and Eco-Scenario (average) for HVAC best and worst case were averaged. For BAU- and Eco-Scenario (high) each best case was used (see Table 103 and Table 104).

Table 103: EU-27 residential energy consumption by use – Baseline, BAU- and Eco-Scenario 2020

EU Energy Consumption	2020	2020	2020	2020
<i>Residential by use</i>	Improve- ment [%]	Improve- ment energy use [%]	Energy Consump- tion in Mtoe	Total improve- ment [%]
HVAC Baseline (average)	0,0	0,0	314,0	0,0
BAU Scenario (average)	25,0	~30,0	286,4	8,8
BAU Scenario (high)	25,0	~30,0	186,3	40,7
ECO Scenario (average)	50,0	~30,0	258,8	17,6
ECO Scenario (high)	50,0	~30,0	167,7	46,6
Water heating/cooking Base	0,0	0,0	72,0	0,0
Lighting Baseline Scenario	0,0	0,0	15,0	0,0
BAU Scenario (average)	50,0	30,0	12,8	15,0
Eco Scenario (high)	75,0	50,0	9,4	37,3
EEE/ICT Baseline Scenario	0,0	0,0	34,0	0,0
Total Baseline			435,0	0,0
Total BAU (average)			405,2	6,9
Total ECO (high)			283,1	34,9

Table 104: EU-27 services' energy consumption by use – Baseline, BAU- and Eco-Scenario 2020

EU Energy Consumption	2020	2020	2020	2020
<i>Services by use</i>	Improve- ment [%]	Improve- ment energy use [%]	Energy Consump- tion in Mtoe	Total improve- ment [%]
HVAC Baseline Scenario	0,0	0,0	92,5	0,0
BAU Scenario (average)	30,0	30,0	84,2	9,0
BAU Scenario (high)	30,0	50,0	78,6	15,0
ECO Scenario (average)	60,0	30,0	75,9	18,0
ECO Scenario (high)	60,0	50,0	64,8	30,0
Heat Baseline Scenario	0,0	0,0	34,0	0,0
Lighting Baseline Scenario	0,0	0,0	6,0	0,0
BAU Scenario (average)	50,0	30,0	5,1	15,0
ECO Scenario (high)	75,0	50,0	3,8	36,7
EEE/ICT Baseline Scenario	0,0	0,0	42,0	0,0
Total Baseline			174,5	0,0
Total BAU (average)			165,3	5,3
Total ECO (high)			144,6	17,2

Through the average BAU-scenario 6.9% of total energy related to residential buildings can be saved. **Average annual energy savings related to HVAC and lighting in residential buildings are an estimated 29.8 Mtoe which equals 51.7 Mt CO₂ emission**

equivalent²¹¹ (or 6.3 % reduction in CO₂ equivalent emissions). Service sector average annual savings are an estimated 5.3% or 9.2 Mtoe which 15.5 Mt CO₂ emission eq²¹² (or 3.7 % reduction in CO₂ equivalent emissions).

As a very optimistic scenario 34.9% in residential sector and 17.2% in the tertiary sector can be saved through the high Eco-scenario compared to the Baseline scenario.

This Eco-scenario would result in annual energy savings of 151.9 Mtoe (240.5 Mt CO₂ eq.²¹³ or 29.4 % reduction in CO₂ equivalent emissions) for residential buildings and 30.0 Mtoe (equivalent to 47.24 Mt CO₂ eq. savings²¹⁴ or 11.7 % reduction in equivalent CO₂ emissions) in services.

2.1.7. EVALUATION OF POLICY OPTIONS

2.1.7.1 Existing and already initiated policy options

In the following paragraph the existing and already initiated policy options are listed according to policy instruments.

Framework Directives (legal acts on EU and member state level)

The improvement of building's energy performance and the need for specific measures has been addressed in the "Energy Efficiency Action Plan". In response, the European Commission proposed the Directive on "The Energy Performance of Buildings" in May 2001. The Directive entered into force on 4th January 2003 (2002/91/EC).²¹⁵ Member States must implement the measures set out in the Directive by 4th January 2006. They may apply for an additional 3 years because of a lack of qualified experts.

Under the Directive on the Energy Performance of Buildings:

- Member States will develop an integrated methodology for calculating the energy performance of a building (Article 3);

²¹¹ This was calculated using the carbon intensity factors from [DG TREN 2008] for the residential sector and carbon emission factor for electricity from EuP EcoReport

²¹² This was calculated using the carbon intensity factors from [DG TREN 2008] for the service sector and carbon emission factor for electricity from EuP EcoReport

²¹³ This was calculated using the carbon intensity factors from [DG TREN 2008] for the residential sector and carbon emission factor for electricity from EuP EcoReport

²¹⁴ This was calculated using the carbon intensity factors from [DG TREN 2008] for the service sector and carbon emission factor for electricity from EuP EcoReport

²¹⁵ Directive 2002/91 of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, OJ L 1, of 4.1.2003.

- Member States will set minimum energy performance requirements on all new buildings and on large existing buildings undergoing major refurbishment (over 1000 m²) (Article 4);
- Energy certificates will be required when buildings are new, sold or rented (Article 7);
- All large public buildings will be required to display this certificate (Article 7.3);
- Boilers and air-conditioning systems over a certain size will be inspected regularly (Article 8 and 9).

This Directive is a key element of the EU's strategy to meet its Kyoto Protocol commitments. Other European Directives and legislative acts relevant to energy efficiency in buildings include:

- The Directive 2006/32/EC on energy end-use efficiency and energy services²¹⁶ was adopted in December 2005,
- The ongoing review of the Directive 92/75/EEC with regard to energy labelling of household products,
- The future implementing measures related to office and public lighting (lots 8 and 9), refrigerators (lot 13) and washing machines (lot 14) lot of the Framework Directive 2005/32/EC on setting ecodesign requirements for energy-using products (EuP),
- The Intelligent Energy-Europe Programme²¹⁷ brings together actions to accelerate the uptake and promotion of energy efficiency and to increase investments in and awareness-raising of renewable energy sources. Existing measures such as 'SAVE' (which concerns the improvement of energy efficiency and the rational use of energy, in particular in the building and industry sectors, with the exception of actions under STEER, including the preparation of legislative measures and their application;), 'ALTENER', or 'STEER' are part of this sub-programme.

2.1.7.2 Evaluation of existing policy options and consideration of further options

The effectiveness of the existing and already initiated policy options needs a critical review in the mid-term. The evaluation should not only determine if the expected improvement potential has been achieved but should provide an understanding of which measure (or combination of measures) achieved the improvement. If the improvement is lower than expected or if the situation is actually getting worse (negative development) it will be essential to adjust the existing policy instruments or even consider other policy instruments.

Improvement and monitoring of statistical data

²¹⁶ http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_114/l_11420060427en00640085.pdf

²¹⁷ http://www.euroace.org/comdocs/CD_120603.htm.pdf

The evaluation if the existing policy options over the next years should be based on solid statistical data. This study comes to the conclusion that the current statistical data provided by EuroStat and other sources are not sufficient. We therefore suggest checking if European statistics could be improved particularly regarding the end-user energy consumption of HVAC, lighting and other building infrastructure equipment. This seems necessary in order to determine the actual source of improvement. ICT applications may also enable metering energy consumption directly at the devices which could improve the data acquisition.

Secondly, the energy certification programme should be designed to help construct and maintain end-use databases to help in the policy analysis. The certification needs to be implemented in parallel with effective information campaigns to explain to the wider public (particularly those buying or looking) and should be promoted through real estate agencies and possibly the insurance industry.

With respect to statistical it seems essential to reflect on regional differences in energy consumption related top building infrastructure. Harmonizing the data acquisition on member state level could improve future assessments of real life situation. ICT again offers an effective means to accomplish this task.

Regulatory watch (initiating and monitoring self-regulation)

- Governments need to find appropriate incentives (not only financial) in order to encourage building owners and users to implement the recommendations provided in the building energy certificates.

On the level of new business development and support of voluntary activities of the industry the promotion of “Energy Contracting” which is currently promote by the Deutsche Energy Agentur “dena” should be considered. The following article of the German international newscast “Deutsche Welle” from 19th March 2007 explains this business concept of shared responsibility.²¹⁸

Energy Contracting: Cutting Emissions While Earning Cash

Eight years ago, the Staudinger High School in Freiburg, a town in southern Germany, decided its buildings needed an energy makeover. Built in 1970, the school was fitted with a heating system that could not be regulated in individual rooms, the lighting was antiquated, and water pumped continually through the toilets. Teachers, parents and friends clubbed together to raise the 270,000 Euros (\$360,000) necessary for the energy renovation and signed a contract with the Freiburg Council, which administers the school. The council guaranteed the investors a percentage of the energy savings over the next eight years. "We already knew about global warming back then and it was obvious that the situation had to change," explained Almut Winzel, a teacher at the school who invested 7,500 Euros (\$9,981) in the energy contracting project. The firm Eco-Watt installed a computer-monitored heating system, new lighting and a

²¹⁸ <http://www.dw-world.de/dw/article/0,2144,2387157,00.html>

water pump. As a result the school now saves around 25-30 percent of its electricity bill and has reduced water use by 65 percent. "That saves the environment, precious resources and money," Winzel said.

Winzel has received an average of 6 percent interest on her investment, which is more than the group originally hoped for. Dieter Seifried, the general manager of Eco-Watt, said the project has been running extremely well. "One of the issues with energy contracting is that you can't exactly calculate the savings at the beginning," he said, adding that even if the project had performed worse than expected, "we would have made around 3 percent." Winzel said that when the energy contract runs out in a few months time, she plans to reinvest her capital in a new one. "It's just such a logical, simple way of reducing energy use that I absolutely want to continue supporting it," she said. Even though energy contracting is a simple idea, it can be difficult in practice because there are so many factors to consider -- such as how to deal with fluctuating oil prices or changing weather patterns. The coldest winter in a century could wipe out the investment completely, whereas a mild winter could award investors an extremely high return. Then there are changing usage patterns to consider -- such as if the school decides to start holding evening classes and potential savings are eaten up by the increased heating and lighting. All of these aspects need to be written into the contract.

Energy performance contracting is proving so successful that even big business has entered the game. Siemens Building Technologies (SBT), for example, has been tendering for such contracts for more than 10 years. "We've seen a growth of about 10 percent in the German market for such energy-efficiency solutions in buildings and demand is especially increasing in the last two or three years," said Mario Lieder, the head of SBT's Energy and Environmental Solutions division in Germany. The company has been involved in energy contracting projects from prisons to swimming pools and the average energy saving is around 20 percent. Although, after an energy refit, the Reinkenheide Clinic in Bremerhaven managed to save 40 percent. Energy contractors are often called in because property owners, whether private firms or public authorities, lack the know-how or the investment capital for an energy refit. But Mario Lieder from Siemens stressed that making buildings more energy efficient doesn't always require large sums. "Sometimes it's not even necessary to invest in hard or software because you can optimize the building management system that already installed," he said. According to Christoph Erdmenger from Germany's Federal Environment Agency, energy contracting is most suitable where there's significant energy use, such as in a building with several floors or a medium-sized company.

As the article indicates the concept of "Energy Contracting" has a certain potential but is of course not fool prove. It seems necessary that member states and local entities should be involved in order to provide strengthen the legal framework for such business concepts. While the buildings sector is receiving important attention in the development of overall energy efficiency policies, this is a cost-effective way to implement energy efficiency improvements in the building sector.

Information and guidelines

- In this conjunction should the Government-private sector partnerships on energy efficiency be promoted and expanded as per Article 12 of the Directive on Energy Performance of Buildings. An example is the expertise centre being established in

Silverdal, outside Stockholm, where Skanska (construction group), in cooperation with the Swedish Environmental Research Institute, the Swedish National Testing and Research Institute and the Royal Institute of Technology, is establishing an international expertise centre on developed environments.

- Another example is the ongoing collaboration of the German Ministry of Environment (BMU), the German Association for Information Technology, Telecommunications and New Media (BITKOM) in the field of “Green Data Centres”. Following a research project conducted on behalf of both entities by the German Boderstep Institute²¹⁹ it is now intended to publish an industry guide on “Energy Efficient Data Centres” in June 2008 as well as a best practise brochure on the same topic by November 2008 in German and possibly English language. This kind of collaboration between national governments and industry associations has the advantage to address and support activities with a focus on regional specifications. On the other hand the European Community should consider a coordination or information support of such regional activities.

Technology development

- The technical progress in the field of ICT – and hereby the potential progress in energy efficiency – is generally influenced by technology development regarding electronic components and materials.
- Electronic Components comprise:
 - Microprocessors (towards: multi-core CPUs)
 - Microcontroller (towards: smaller chip sized packaging)
 - Logic devices (towards: field-programmable gate array, memory embedding)
 - Memory (towards: non volatile, multi chip modules)
 - Power IC (towards: power management and display driver applications)
 - Printed circuit board (towards: multi layer, electro-optical, embedded devices)
 - Micro electro-mechanical systems (towards: RF switch applications)
 - Liquid crystal display panels (towards: larger size, LED backlight)
 - Light emitting diodes (towards: commercial lighting and display applications)
 - Other components such as sensors, connectors, switches, cables
- The performance improvement of electronic components is related to:
 - advanced semiconductor materials (e.g. low-k dielectric materials, photo resist and mask materials, gases and wet chemicals)

²¹⁹ <http://www.borderstep.de/details.php?menue=69&subid=84&projektid=127&le=en>.

- electronic packaging materials (e.g. for leadframe metals, molding compounds, die attach, solders, adhesives, encapsulation materials)
- Functional materials (e.g. dielectrics, magnets, metal electrodes, glass and glass fibres, polymer films or substrates, organic solutions for OLEDs, other composites)
- Furthermore research and technology development will have to address topics such as:
 - Production technologies (e.g. roll-to-roll for low cost polymer electronics versus high-end 3D wafer level packing)
 - Reliability and long life stability (e.g. system integrated condition monitoring)
 - Alternative energy supply (e.g. energy harvesting technology for sensors)
 - Harmonisation of interfaces (e.g. standardised network interfaces for better interoperability and upgrading capability)
 - Algorithms and software development which are necessary to integrate the technical solutions mentioned above (e.g. calculate appropriate heating/cooling requirements).

With respect to political measures in support of future technology development it is necessary to reflect on the global structure of the electronics industry. In the critical upstream electronic components and materials market non-European industry mainly from Japan and the United States are dominating the market. This fact should not discourage R&D support for the remaining materials, semiconductor, components, and printing circuit board industry in the European Union. In the future, technical know-how will be necessary particularly on the so called micro-system integration level. This means that we are already recognising a technological gap between advanced chip technology (continuous miniaturisation of active devices such as Processors and Memory according to Moore's law) and the printed circuit board level. Micro-system integration is the technological link between even smaller devices and the substrate (board). It consists of chip encapsulation and interconnection technology, board structuring and device integration technology, optical components and photonic packaging, as well as thermal management. Further essential know-how is system design, test, and simulation capabilities. Due to the fact that the European electronics industry is highly specialised (e.g. particularly the printed circuit board industry) customised applications which are mostly necessary in building, machinery and automation can be realised. Such projects should be supported by linking system integration know-how with respective small and medium sized enterprises. Finally, software development is an indispensable part of efficient ICT. System integration should not end on a hardware level but should merge with software design.

2.1.8. CONCLUSIONS SUBTASK 2.1

- This subtask 2.1 shows that there is significant improvement potential in Europe for residential buildings in northern Europe, and service buildings (estimated to reach 181.9 Mtoe energy savings in an Eco-scenario (equivalent to 2115.5 TWh) compared to 39 Mtoe (453.6 TWh) energy savings in a BAU scenario). However, the difference between the BAU and Eco-scenario shows that recommendations are necessary to contribute to the uptake and large scale deployment of ICT-based energy efficient buildings, and help reach the best objectives. These include: Improvement and monitoring of statistical data, regulatory watch (initiating and monitoring self-regulation), information and guidelines and technology development.
- The energy saving capabilities based on ICT technologies rely on the functionalities enabled by ICT equipment. Indeed, the analysis shows that ICT is the “final element” to an effective system such as a low energy building, making the building infrastructure “smart” based on the following main functionalities:
 - Monitoring of conditions (sensor)
 - Transmission of sensor data (network)
 - Processing, storage and display of data (software-based control)
 - Actuating in response to the controllers command (actuator)

These functionalities allow developing **connectivity** in the building (ICT links single elements in the building infrastructure and enables an automatic reaction to changing conditions), **flexibility** (ICT enables an effective retrofitting or modification of individual equipment in the existing building infrastructure), **transparency** (ICT provides useful information to the system administrator or user through sensor data) and **ambient intelligence** (ICT provides the vision of a technology that will become invisibly embedded in the building infrastructure).

2.2. SUBTASK 2.2: INDUSTRIAL EQUIPMENT AND AUTOMATION

2.2.1. INTRODUCTION

This subtask has the objective to provide data on energy consumption related to industrial equipment and the current potential of ICT applications in support of higher energy efficiency. Industrial equipment comprises all kinds of machines including large electrical tools, robots, cranes, engines, fans, pumps, galvanic baths, incinerators, furnace equipment, ovens, shakers, and coverer belt systems. Such industrial equipment is commonly applied in energy-intensive manufacturing for raw material refinery, preliminary product manufacturing, and of course for the production of final goods.

Energy-intensive manufacturing includes for instance: industry sectors such as food, paper, bulk chemicals, petroleum refining, recycling, glass, cement, steel, and aluminium. As the name indicates the energy-intensive manufacturing industries consume large quantities of energy or have high energy intensities on a spot. Due to structural changes, large energy-intensive manufacturing is declining in the European Union. Global competition has put high pressure on costs and performance in these sectors, shifting production to regions with easy access to resources and labour. This situation has led to a high level of specialisation and system automation (automation of industrial processes) with highest efficiency standards in the remaining industry in Europe. This trend also implied that energy efficiency has been recognised already as an important economical factor. The industry therefore has addressed this issue in the past and improved their industrial equipment accordingly (including through industrial process system automation). The solutions are very specific and difficult to generalise. Trade-offs derive from particular technologies, equipment, and process know-how.

Final products and goods manufacturing is somewhat less energy-intensive on a spot, however, the diversity of large, medium, and small size production is contributing to overall energy consumption probably more than the energy-intensive manufacturing.²²⁰ Final goods manufacturing includes for instance food processing, printing and press, vehicle and car industry, aircraft and aerospace, production equipment and machine tools, semiconductors and electronics, medical equipment and pharmaceutical industry. As a general consideration, it seems feasible to assume that due to the diversity of final goods manufacturing energy efficiency has not yet reached the highest priority and can be improved. Improvement potential derives from energy efficient equipment, process automation, new technologies offering system solutions, and a useful application of ICT.

The energy consumption related to industrial equipment and processes is mainly determined by:

- Electrical drivers including electrical motors, pumps and fans
- Furnace, smelter and incineration equipment
- Galvanic bath

The following study will set a focus on electrical drivers. Furnace equipment and galvanic baths are not investigated because generalisation and extrapolation from case studies is difficult in this field. The study provides:

- Comparative market and energy consumption data
- Technical status and trends
- Case studies on ICT applications with energy saving potential

²²⁰ Exact figure could not be obtained.

Finally we summarise and discuss the findings of the study which includes the following tasks:

- Systematisation of the identified technical trends
- Qualitative and quantitative assessment of energy saving potential
- Evaluation of policy options

2.2.2. ELECTRICAL DRIVERS, MOTORS, PUMPS AND FANS

2.2.2.1 Comparative market and energy consumption data for electrical drivers

Status 2005

The updated DG TREN report 2008²²¹ on “European Energy and Transport – Trends to 2030” states an energy consumption of 324.5 Mtoe for the industry sector of EU-27 in 2005 (see Table 105).

Table 105: Energy consumption in Mtoe for EU-27

EU Energy Consumption	2005	2005	2020	2020
Final demand by sector	%	Mtoe	%	Mtoe
Industry	27,8	324,5	27,3	367,7
Residential	26,3	307,0	24,9	336,0
Services/Agriculture	14,9	173,7	15,2	205,5
Transport	31,0	361,7	32,5	438,6
Total	100,0	1.166,9	100,0	1.347,8

Recent data on the energy consumption related to electrical drivers (motors) derive from the EuP Preparatory Study Lot 11 “Electric motors 1-150 kW and pumps, circulators, fans”.

According to the Lot 11 Study on **pumps** (AEA Technology, 2008) amounted the EU-25 stock on pumps to **17 million units** with respective annual electricity consumption of **136.6 TWh**.

According to the Lot 11 Study on **fans** (Fraunhofer ISI, 2008) the existing product stock in EU-25 is considerably high with a total of **87.3 million units**. The respective annual electricity consumption is **243.7 TWh**.

The Lot 11 Study on **motors** (ISR University of Coimbra, 2007) provides EU-15 stock assumptions and respective electricity consumption for **low voltage AC motors** in the industrial and tertiary sector for the year 2005.²²² The following EU-27 stock estimates

²²¹ European Commission Directorate-General for Energy and Transport: *European Energy and Transport - Trends to 2030*, Update 2007, Belgium 2008

²²² AC motors have already a dominant market share of 96.2%. The DC motors share is 3.8% declining. The AC motor segment can be further divided into three-phase induction motors (87%), synchronous

(see Table 106) are based on extrapolations from EU-15 data of the Lot 11 study.²²³ According to this calculation the EU-27 stock of motors in 2005 was **100.8 million units with an annual energy consumption of 91.2 Mtoe (1,060.4 TWh)**.

Table 106: EU-15 stock and EU-27 stock estimates for motors in 2005

Segment	Motor type	Stock EU-15 in Mio units	Market Share in %	Stock EU-27 in Million units	Market Share in %
Industry	0.75–7.5kW	49.00	86.2	56,4	86.2
	7.5–37.0kW	5.74	10.1	6.6	10.1
	37–75 kW	1.30	2.3	1.5	2.3
	>75 kW	0.81	1.4	0.9	1.4
	Sub Total	56.85	100	65.4	100
Tertiary	0.75–7.5kW	27.70	90.1	31.9	90.1
	7.5–37.0kW	2.75	8.9	3.2	8.9
	37–75 kW	0.27	0.9	0.3	0.9
	>75 kW	0.04	0.1	0.05	0.1
	Sub Total	30.76	100	35.4	100
All Motors	Total	87.61	100	100.8	100

As it can be seen in Table 106, this is not completely related to the industry sector. About 20 Mtoe are related to motors in the tertiary sector (services). But as the technological improvement potentials are assumed to be the same, the calculation is done for motors of the secondary and tertiary sector together.

The energy consumption derived from the Lot 11 study seems to cover only the electricity consumption. The total electricity consumption of motors, pumps and fans exceed the electricity consumption according to EuroStat 2007 for the industry sector, because it covers also parts of the tertiary sector and because the energy consumption of pumps and fans is covered to some extent by the motors. For further calculation (BAU- and Eco-scenario) only the figures for motors will be used.

motors (5%), universal motors (4%), and single phase motors (4%). The three-phase induction motor segment is further subdivided into size classes or number of poles.

²²³ The Figure 2-5 “EU-15 and EU-25 market information on low voltage AC motors” of the Lot 11 Report “Motors” No 2 (page 39) indicates that the stock volume for EU-25 (respective EU-27) is only by 10% slightly larger than for EU-15.

Table 107: Electricity consumption of the industry sector in EU-27

EU Electricity Consumption	2005	2005	2020	2020
Industry by use	%	TWh	%	TWh
motors		1.060,4		1.344,9
pumps		136,6		166,3
fans		243,7		345,3
others				
Total		1.440,7	0,0	1.856,5
Total by EuroStat 2007		1.127,4		1.430,1

Outlook for 2020

According to the Lot 11 Study on **pumps** the energy consumption of pumps in the BAU-scenario (no improvement of the energy efficiency) in 2020 raises from above named 136.6 TWh caused by 17 million units to **166.3 TWh caused by 20.7 Mio units in EU-25**.

The energy consumption of **fans** will increase, according to the BAU-scenario of Lot 11 on fans, to **345.3 TWh consumed by 126.5 million units**.

The energy consumption of motors in 2005 is calculated with the same stock extrapolations as above for EU-27. It is assumed that the average energy consumption per unit will not improve over time. According to this, **127.8 million motors in EU-27 will consume 1,344.9 TWh (115.6 Mtoe) in 2020**.

It can be assumed, that with rising energy / electricity costs, the share of more efficient motors, pumps and fans will increase. But, as these are products with very long life cycles, the effects will probably not be seen in 2020 yet. With additional legislative measures, the market penetration of more efficient devices can be supported.

According to the EuP Lot 11 study the savings are mainly achieved through more efficient hardware than through ICT. The most important technology in this area seems to be variable frequency drives.

2.2.2.2 Technical status and trends

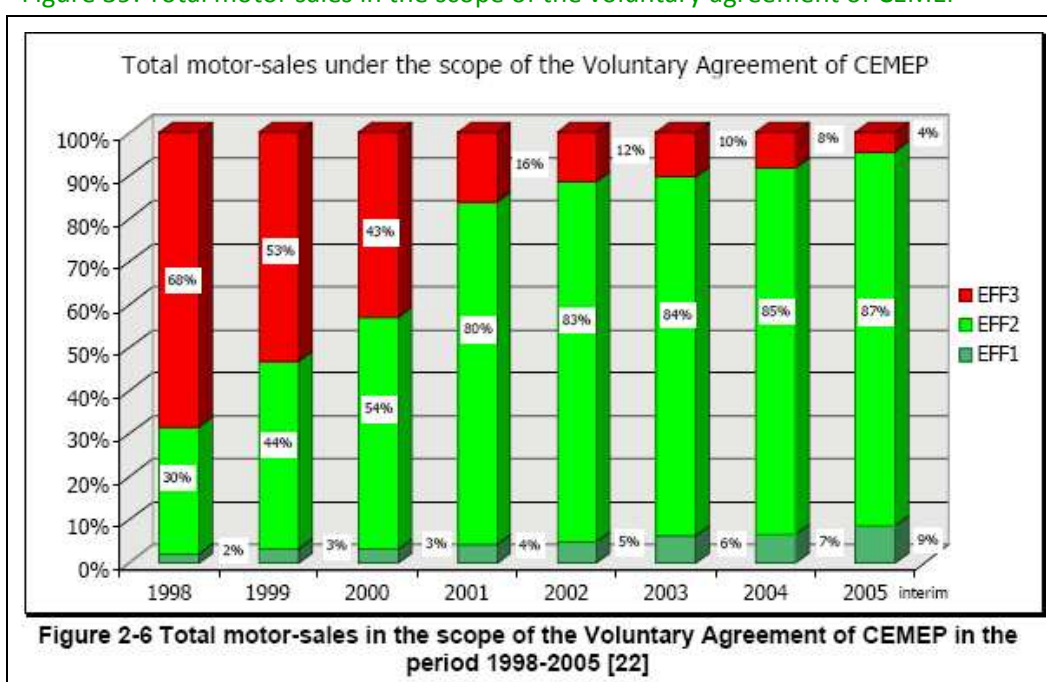
Electrical drivers, using advanced microelectronic solutions, have a good potential for improved energy efficiency. The EC (European Commission) in collaboration with the C.E.M.E.P.²²⁴ (European association of manufacturers and the European regulating body) developed a voluntary “energy efficiency” classification scheme (EFF 3 [low], EFF 2 [medium], EFF 1 [high]) based on the conversion efficiency for 2- and 4-pole squirrel cage motor. Three-phase drivers as well as permanently magnetised synchronous motors have principally lower rotor losses and therefore even better conversion efficiency.

In the European Union, the original target of CEMEP/EU agreement was to reduce joint sales of EFF3 motors by 50% after agreement period (2003). The aim was completely

²²⁴ Comité Européen de Constructeurs de Machines Electriques et d'Electronique de Puissance

achieved, since EFF3 motor sales decreased from 68% in 1998 to 4% in 2005. On the other hand, penetration of EFF1 efficiency motors was very small until now. The main reason for this situation is due to the fact that the motor market is largely an OEM market, in which OEM purchases represent 80-90% of the sales. This large share of the market combined with the higher EFF1 prices, which typically are 20-30% above EFF2 motors price, leads to a low penetration of EFF1 motors. Motor manufacturers were able to introduce EFF2 motors with a similar price to EFF3 motors, by improved design, manufacturing and more competitive marketing. The updating of this voluntary agreement is now being prepared. Figure 39 shows the achievements of the voluntary agreement of CEMEP and the EC.

Figure 39: Total motor sales in the scope of the voluntary agreement of CEMEP



ZVEI (2006) provides an interesting assessment of the improvement potential related to energy saving of electrical drivers (low voltage motors). Three measures are distinguished:

- High efficiency motors HEM (10% improvement)
- Electronic rotation speed control (30% improvement potential)
- Mechanical system optimisation (60% improvement potential)

The following are examples for the application of energy efficient speed controls.

One important component of an electrical drive is a frequency converter. In Germany electric energy from the public network comes in form of AC voltage or three phase voltage with a constant frequency of 50 Hz. For the speed regulation of a three-phase motor the frequency as well as the voltage needs to be changed. This is done in an electrical frequency converter, which converts alternating current (AC) of one frequency to alternating current of another frequency, and is controlled by a

microcomputer and its software. Modern frequency converters are available for capacities from a few Watt to several 1,000 kW and were constantly improved in the last years due to improvements of microelectronics. ZVEI names an example of a fan (nominal power: 7.5 kW) which is used in an extraction system of a wood manufacturing industry. If the fan is driven by a three-phase motor controlled by a **frequency converter**, 8,400 kWh per year can be saved compared to mechanical throttling of the delivery flow [ZVEI 2006].

Another possibility to reduce energy losses during acceleration and brake applications is to use a **frequency inverter** which converts direct current (DC) to alternating current (AC). Losses during the acceleration phase can be completely avoided with a frequency inverter because it constantly increases the frequency consistent with the rotation speed. If the frequency inverter is connected with an energy recovery system, the released kinetic energy can be supplied into the electricity network. As a side effect the motor will have to stand less thermal impact which increases the potential lifetime. As an example of use ZVEI names an industrial centrifuge [ZVEI 2006].

High efficiency motors (HEM) are more efficient due to the increased use of active material and the therefore reduced losses. For motors with a power rating of 1 kW the efficiency gain is about 8%, with a power rating of 100 kW the improvement is still up to 1.5%. According to the ZVEI study, 30 Mio of old motors will be replaced in the next years in Germany. The improvement potential is calculated via the assumption that all of these motors are replaced with high efficiency motors. An average **efficiency improvement of 4%** is estimated. Based on these assumptions 5.5 TWh/a or 2.5 Mt CO₂ eq.²²⁵ can be saved in Germany due to HEM. This is a very rough estimation, based on theoretically improvement potentials. In reality, not all stock is replaced with the best available technology.

These improvements lead to reduced energy consumption, but they are not directly related to ICT applications. However, the following case studies provide examples of the application of ICT in conjunction with these general technical trends.

2.2.2.3 Case study: Variable Frequency Drives

Topic and technological concept

A big innovation in energy savings was the variable frequency drive (VFD). The variable frequency drive added efficiency to systems by making it possible to speed up and slow down electric A.C. motors based on demand. The age of running an electric motor full blast all day long ended when this innovation, the variable frequency drive, was first used in commercial HVAC.

²²⁵ The translation of energy consumption into CO₂ eq. was done with the VHK EcoReport.

ICT Application

Variable frequency drives work by changing the frequency of the power supplied to the motor. By changing the frequency of the power the speed can be changed. Blower fans and pumps can be modulated based on demand. Variable frequency drives need a method of control to modulate the electric motor. Some variable frequency drives have a built in controller which, when programmed, will control the motor based on a set of instructions in the program. Other variable frequency drives need an external controller which will signal the variable frequency drive when to speed up and slow down. Modern systems rely on a direct digital control system and application for this function. Based on an input variable the direct digital control system will send a signal to the drive to speed it up or slow it down depending on the direct digital control programming.

Energy Saving Potential

Other names for variable frequency drives are variable speed drives, AC drives, and adjustable speed drives. These systems often pay for themselves within a few years by offering energy savings through precision control of the HVAC based on actual demand for heating and air conditioning. If there is only a need to run the HVAC system at 50% then the system is programmed to run the HVAC system at 50% and the results are energy savings to the customer. Variable frequency drives or variable speed drives help save in energy costs for the consumer.

The leading HVAC system manufacturer DAIKIN of Japan developed “Eco Rich” hybrid hydraulic pump system. They adapted the motor inverter technology for use in hydraulic pump systems. The electric power consumption level was cut by 50% due to lowering the rotation speed of the motor in standby.

Another example for the use of VFDs is taken from the paper industry: During the production process of paper the charging level of the pulper varies a lot. If the pulper drive (ca. 400 kW, 2,150 MWh/a) operates with constant rotation speed this leads to quality problems of the paper due to unrequested shortening of the fibre during low charging levels. These problems can be solved with a speed-controlled drive. Such a drive lowers its speed during low charging levels which avoids unrequested shortening of the fibre as well as the insertion of soil. Also the **energy consumption will be reduced by 40%** [ZVEI]. To achieve this, the speed control needs to be connected to sensors which check the charging level. The speed control needs to be programmed for different charging levels or automatically calculates the accurate rotation speed for each individual charging level.

According to the ZVEI study, today approximately 12% of all motors (in Germany) are equipped with energy efficient rotation speed control. For about **50% of all motors such kind of speed control would be reasonable**. The **potential energy savings** per installed unit were estimated with **40%**. The total energy consumption was assumed to

be 165 TWh/a. Based on these assumptions 22 TWh/a could be saved with energy efficient speed controls (in Germany). This equals 10.1 Mt CO₂ eq.²²⁶ per year. In this calculation only the savings in the use phase of the drives is calculated. Potential differences during in the production process as well as the increased life cycle of devices due to less abrasion caused by the speed control are not taken into account. **This is a very rough calculation, but as data is limited, it gives an impression of the improvement potential.**

2.2.2.4 Case study: ICT-enhanced solutions for escalators

Most escalators run on full speed all the time. Thereby electricity is continuously consumed even there is no passengers on the escalator or conveyor. Much energy can be saved if the speed of the motor drive can be adjusted according to the passenger transportation frequency. This can be achieved technically by the use of sensors or light barriers in passenger guide bars and controllers such as frequency inverters to adjust the speed of the motor. Usually the sensors are integrated in the handrail entry caps to detect reflection from individuals and objects. In case of widely fluctuating operating conditions, a light barrier must be installed in the skirting area of the escalator. A simpler arrangement using a two-speed motor drive system can be such that it operates in slow speed when there is no passenger boarding. Once passengers enter a boarding zone, the speed of the escalator is resumed to normal before the passengers actually board on the escalator or conveyor. **By such intermittent-run escalators an energy saving of up to 30% can be achieved. If a variable speed drive is available, a saving of up to 60% can be achieved.**²²⁷

Hurst (2007) names another possibility to reduce the energy efficiency of escalators without actually reducing the running speed, which leads in his opinion to more accidents and does not meet US safety codes. With a so-called soft-start the speed of the escalators stays unchanged, but the energy consumption is reduced when fewer people are on the escalator. The device incorporates a solid-state soft starter with patented energy-saving technology that constantly monitors the workload of the motor. **The technology matches the voltage to the motor load in order to supply the precise amount of energy required to maintain the escalator at normal operating speed.** In a recent test by Nevada Power Co., the electric utility for southern Nevada, on an escalator motor at a major Las Vegas casino, Power Efficiency's technology **reduced average power consumption by 33%** [Hurst 2007].

²²⁶ The translation of energy consumption into CO₂ eq. was done with the VHK EcoReport.

²²⁷ Electrical and Mechanical Services Department – The Government of the Hong Kong Special Administrative Region : *Guidelines on Energy Efficiency of Lift and Escalator Installations*, 2000 Edition, online available at:

http://www.emsd.gov.hk/emsd/e_download/pee/guidelines_on_ee_of_lift&escalator_installations.pdf

2.2.3. SYSTEM AUTOMATION AND POWER MANAGEMENT OF INDUSTRIAL EQUIPMENT

Additional to the above named equipment optimisations, saving potentials can be exhausted by using ICT applications for system automation.

Network capability and network control are keywords with respect to directly controlled drivers (motors). The most common bus interfaces is a 100 Mbit/s Ethernet and standard internet protocols which allows real time communication (see also section 2.1.2.8). With respect to the hardware it is noticeable that commonly used decided logic components are replaced by field programmable gate arrays (FPGAs) which provide more flexibility in design of the hardware and the application of software. This also allows a virtual product development based on models of component.²²⁸

2.2.3.1 Case study: ABB

Topic and technological concept

According to ABB²²⁹ about three-quarters of all motors are used to run pumps, fans or compressors. In these applications, speed can often be reduced and energy saved. This can be accomplished with frequency converters, which adapt motor speed to match the required pressure or flow, instead of allowing the motor to run at full speed all the time (see also 2.2.2.3). With supporting software tools these energy savings can be increased even further.

ICT Application

ABB developed software for „intelligent pump control” in the frequency converter. This is an optional software tool for low voltage frequency converters of the ABB industrial drives series, which especially meets the requirements of water and waste water management, industrial facilities and other pump applications. The intelligent pump control contains six integrated pump control functions. Two of these functions are especially useful in terms of energy efficiency.

One of these functions is the “pump priority function”. This function balances the operating times of all pumps in the system over a long period of time. Thereby the planning for maintenance becomes easier and the energy efficiency will be increased as the pumps operate closer to optimum operating point. An example is also an application which has higher loads during the day. The drive can be programmed to run pumps with higher capacities during the day and smaller ones over night.

Another function is the sleep function, which increases the pressure or water level before powering down. Thereby the idle period of the pump will be increased which

²²⁸ VDI Nachrichten No. 44, November 2nd, 2007, page 21: *Direktantriebe werden für die Industrie immer attraktiver* (in English: Direct controlled drivers are more and more attractive for the industry).

²²⁹ ABB: <http://www.abb.com/cawp/seitp202/e8bead7ae61f4abac12572d8003d99b3.aspx>

leads to reduced energy consumption. Additionally unnecessary starts and stops are avoided.

Energy Saving Potential

In the last 10 years, the estimated energy savings achieved only by frequency converters for the speed control of pumps and fans supplied by ABB, amount to 50 TWh per year.²³⁰ However, the share of energy savings caused by actual ICT appliances is difficult to quantify.

According to ABB, in the Indian cement industry with the use of VFDs instead of cascade converters (also called Slip Power Recovery Systems (SPRS)) to control the speed of process fans, the energy consumption can be reduced from 90 kWh/ton to about 70 kWh/ton of cement produced.²³¹ Again, it is difficult to quantify the role of ICT in such applications.

2.2.3.2 Case study: Electrical motor monitoring

According to a report by GE Global Research on “Distributed Wireless Multi-Sensor Technologies” [GE 2008]²³², electric motor systems consume about 60% of all generated electric power and 70% of all electricity in industrial applications in the United States. This is quite similar to the situation in Europe. As stated above ZVEI estimates the energy consumption of motors in Germany about two third (64%) of the whole generated energy, which amounts to 161.2 TWh for motors only in Germany.

GE estimates that energy savings of 122 trillion BTUs²³³ (approx. 36 TWh) until 2020 can be achieved through the use of motor condition monitoring.

The report is the result of a programme which main goal was “to develop wireless sensor technology that would be commercialized and adopted by industry for a various set of applications. Many of these applications will yield significant energy savings.” One example where the potential energy savings could be estimated focused on equipment condition monitoring and in particular electric motor monitoring.

To monitor load conditions and energy usage, detect degradations of energy efficiency, predict failures, and improve maintenance strategy, there is a need to create a reliable, robust wireless communication system and establish a long-lasting device that can be

²³⁰ ABB: <http://www.abb.de/product/ap/seitp322/5007d32fbf41425bc12572e4003116d7.aspx>

²³¹ ABB: *Variable Speed Control of Fans in the Cement Industry – DriveIT ACS 1000 Medium Voltage Drives for speed and torque control of 315 kW – 5,000 kW motors*, online available at:

[http://library.abb.com/GLOBAL/SCOT/SCOT216.nsf/VerityDisplay/96FC1E0F36A992A2C1256D0A004A08DE/\\$File/Chettinad%20CS.pdf](http://library.abb.com/GLOBAL/SCOT/SCOT216.nsf/VerityDisplay/96FC1E0F36A992A2C1256D0A004A08DE/$File/Chettinad%20CS.pdf)

²³² Daniel Sexton : *Distributed Wireless Multi-Sensor Technologies*, by GE Global Research prepared for The U.S. Department of Energy; February 19, 2008
<http://www.osti.gov/bridge/servlets/purl/926169-WjRGDo/>

²³³ British Thermal Unit: 1,000,000 BTU = 293.06 kWh

obtained at a reasonable cost. Therefore the key technical challenges faced on the GE 2008 project were:

- Wireless communication reliability and coexistence
- International regulatory restrictions
- Wireless system range
- Device power consumption
- Device cost
- Mechanical robustness

One example for realised energy savings during the project was by monitoring of compressed air at a small specialty paper mill by Sensicast Systems. Therefore, wireless sensors were used to monitor airflow and pressure across the total compressed air system for this small facility. In this mill, 335 MWh of energy could be saved during one year, resulting in a 30% savings in operating costs for the compressed air system. Such systems could effectively be applied in any facility that requires a substantial amount of compressed air in their operations.

Another example for energy saving potential through wireless sensors is the mining industry. In mining operations, 8% of the energy is consumed by ventilation systems. Energy savings of 65% were enabled by wireless sensing for ventilation control, measured by NewTrax technologies. Wireless sensors were placed on vehicles and heavy equipment within the mine. Also, the mine personnel carry wireless sensors. Thereby the system senses where the equipment is used and people are present. Ventilation fans are energised only where needed and to the extent that fresh air is required. VRDs are used to control fan speed and airflow. Therefore, **potential energy savings in underground mine operations of 5% can be estimated**. For the four mines listed in the DOE motor market Assessment, this would represent 3.39 TWh per year of energy savings. [GE 2008]

According to the GE report, estimated 0,354 Quad²³⁴ (approx. 373 PJ) energy could be saved by motor condition monitoring with an adoption rate of 25%. [GE 2008]

2.2.3.3 Case study: Traffic management system (TMS) for elevators

Topic and technological concept

The energy consumption of elevators is mainly related to the motor and can be reduced by hardware optimisation such as using high efficiency motors (see also 2.2.2.2) or light weight materials for lift car decoration. But there are also operating options to reduce the energy consumption of elevators. For lift banks with more than one lift car, for the second (or more) lift car a “standby mode” is usually introduced.

²³⁴ 1 Quad = 1.055 EJ = 10¹⁸ J

This standby mode will be entered during off-peak hours and the lift car does not respond to passenger calls. If the lift car is operated with an individual drive, the drive should be shut down completely in standby. Another possibility is to shut off the ventilation fan and lighting (together with e.g. music or displays inside the lift) while a lift car is idle.²³⁵ The following case study combines ICT-control and operation management in a so called traffic management system.

The world's leading elevator manufacturer Schindler²³⁶ has introduced a control system called Miconic 10. This controller unit uses a traffic management system (TMS) that brings people to their destinations faster than any other elevator control. By grouping people travelling to the same floor, Miconic 10 reduces the number of intermediate stops and thereby improves the elevator system efficiency.

ICT application

A special traffic management system uses a destination control system where the user chooses its destination floor (via an alphanumeric keyboard or a touch screen) before entering the elevator. Inside the elevator are normally just displays to show the destination but no further user interfaces. The TMS uses the information on destination floor and number of people to group people travelling to the same floor, allocate the user to the right elevator and reduce the number of intermediate stops. Often these systems are combined with security systems (identification via pin codes or badges to allow access to certain areas/floors) or additional individual services (e.g. avoiding transportation of goods together with customers).

Energy saving potential

The main goal of the TMS is thereby to improve the efficiency of the lifts by transporting people faster and more comfortable, but there is also a potential to save energy by reducing the number of stops and thereby the number of brakes and accelerations. Also additional energy saving functions, like switching of the light, music and display inside the elevator when empty, could be possible.²³⁷

Modern elevators use sophisticated software to control the elevator. Some systems "learn" where to position cabs at specific times (e.g. in the hall in the morning, upstairs at closing time). According to Sachs (2005) **advanced elevator control systems can save 5% of the energy compared to systems with the same hardware and "basic" software.**

²³⁵ Electrical and Mechanical Services Department – The Government of the Hong Kong Special Administrative Region: *Guidelines on Energy Efficiency of Lift and Escalator Installations*, 2000 Edition, online available at:

http://www.emsd.gov.hk/emsd/e_download/pee/guidelines_on_ee_of_lift&escalator_installations.pdf

²³⁶ Schindler; http://www.schindler.com/group_index/group_tech.htm

²³⁷ Schindler; <http://www.schindlerid.com/index.php?page=html/EN/introduction.htm&lgvers>

2.2.4. SYSTEMATISATION OF THE IDENTIFIED TECHNICAL TRENDS

Electromechanical and electronic measurement and control solutions have a long tradition in factory and process automation. ICT applications support the growing demand of controlling manufacturing equipment and processes in real time, as well as handling products and logistics information fast and safely.

Sensors for measuring thermal, mechanical, electrical, optical, acoustical, and chemical conditions are key applications of ICT. The miniaturisation and digitalisation of sensors based on advanced semiconductor and MEMS²³⁸ technology is the main driver to increase functionality such as higher speed and accuracy.

With the technological progress in ICT the factory and process automation technology takes a great step forward towards:

- Real-time control
- Event prediction
- Process visualisation
- Micro-sensors with integrated digital data processing
- Energy autarkic sensors based on energy harvesting technology
- Build-in or mobile wireless sensor networks

Next-generation automation system technologies will incorporate advanced network technologies, such as IP-v6, open-platform technologies, including Linux, database technologies, wireless technologies, as well as high-reliability sensor technologies.

One ICT based application which illustrates the role of ICT in factory and process automation is the use of Wireless sensor networks. Wireless sensor networks (WSN) allow a more precise control of machinery, equipment, manufacturing lines and processes. WSN consist of autarkic sensor nodes configured in a wireless network. This technology is still in its infancy, but has huge potential in the field of automation. However, the contribution of WSN to energy efficiency is not yet quantifiable.

ICT can improve the energy efficiency of industrial processes by the following aspects:

- connectivity
- flexibility
- transparency
- ambient intelligence
- miniaturisation

These aspects have been comprehensively described already in chapter 2.1.5.

²³⁸ MEMS: Micro electro mechanical systems

2.2.5. ENERGY SAVING POTENTIAL OF ICT-ENHANCED INDUSTRIAL EQUIPMENT AND AUTOMATION

Two scenarios are calculated for the improvement of industrial equipment and automation, mainly based in improved motor efficiency. The situation of fans and pumps is not further explored as the figures for motors already cover fans and pumps to some extent. Due to missing statistical data, rough assumptions were made for the calculation. The motors were assigned to different levels of improvement:

- High: 15% of motors (have a high level of improvement)
- Average: 50% of all motors
- Low: 35% of all motors

It is further assumed, that the “average” motors consume together 50% of the electricity. As a pragmatic approach for the scenarios, estimated 40% improvement potential was assumed. For the BAU-scenario 25% of this group will be replaced by “improved” motors, For the Eco-scenario, 50% will improved until 2020.

Table 108: BAU- and Eco-Scenario for motors

		2020	BAU		ECO
Level of improvement		Number of units [Mio]	Energy consumption without improvement [Mtoe]	Energy consumption 25% stock exchange [Mtoe]	Energy consumption 50% stock exchange [Mtoe]
high	15% of Motors in EU-27	19,2			
average	50% of Motors in EU-27	63,9	57,8	52,0	46,3
low	35% of Motors in EU-27	44,7			
Total		127,8	115,6	109,9	104,1

The BAU-scenario shows an improvement potential of 5.8 Mtoe compared to the scenario without any improvements. For the Eco-scenario the improvement potential is 11.6 Mtoe. This results in reduced emissions of respectively 30.9 Mt CO₂ eq and 61.8 Mt CO₂ eq²³⁹.

2.2.6. EVALUATION OF POLICY OPTIONS

2.2.6.1 Existing and already initiated policy options

In the following paragraph the existing and already initiated policy options are listed according to policy instruments.

Framework Directives (legal acts on EU and member state level)

Directive 2005/32/EC on establishing a framework for setting of ecodesign requirements for energy-using products (EuP) is the legal framework in which

²³⁹ This was calculated based on the CO₂ emission factor from the EuP EcoReport Tool developed in the framework of the EuP Directive 2005/32/EC where **1000 kWh (Electricity)= 458.214 kg CO₂ eq.**

minimum requirements on energy efficiency of electrical motors, pumps and fans are going to be set in the near future. EuP preparatory study Lot 11 (related to motors, pumps and fans) proposes following implementing measures (IM) to tackle the energy consumption issues related to this equipment under the EuP:

- Minimum energy efficiency requirements (MEPS)
- Mandatory energy labelling
- Define new A* and A** labels, where necessary²⁴⁰
- Requirement for display the real value of the overall static efficiency of the products (e.g. in catalogues)
- Public information data base by the European Commission based on standardised data delivered by the manufacturers²⁴¹

Moreover, increased attention to the product design stage (manufacturing phase) should be realised through the other EuP preparatory studies related to eco-design which will increase awareness of the impacts related to the manufacturing phase.

Regulatory watch (monitoring self-regulation and voluntary agreements)

Different voluntary initiatives already exist, aiming in the same direction as the above mentioned legal measures:

- Ecopump - Circulators Labelling Commitment²⁴²
- Energy+ Pumps Project²⁴³: A marketing initiative to promote higher efficiency circulators, supported by the Intelligent Energy Programme of the European Commission
- Voluntary agreement CEMEP/EU: Efficiency Classification and market reduction of EFF3
- The European Motor Challenge Programme²⁴⁴ – a voluntary programme instituted by the European Commission – already helps organisations improving the efficiency of

²⁴⁰ Hugh Falkner (AEA Energy & Environment): *EuP Lot 11 – Circulators in buildings*, Task 8, April 2008, online available at: http://www.ecomotors.org/files/Lot11_Circulators_1-8_issue5_110408_final.pdf

²⁴¹ Peter Radgen, Julia Oberschmidt, W.T.W. Cory: *EuP Lot 11 – Fans for ventilation in non residential buildings*, Task 8, Fraunhofer ISI, April 2008, online available at: http://www.ecomotors.org/files/Lot11_fans_1-8_280408_final.pdf

²⁴² www.europump.org

²⁴³ www.energypluspumps.eu

²⁴⁴ Hans De Keulenaer, Ronnie Belmans, Edgar Blaustein, David Chapman, Anibal De Almeida, Bruno De Wachter, Peter Radgen: *Energy Efficient Motor Driven Systems ...can save Europe 200 billion kWh of electricity consumption and 100 million tonne of greenhouse gas emissions a year*, The Motor Challenge Programme, April 2004, online available at: http://www.mcpeurope.net/4em/upload/eng_EEMotors-EN.pdf

their motor driven systems. A 4-year package of measures is proposed to achieve a switch to energy efficient motor driven systems, which should include the following:

- Introduction of audits of energy systems in industrial installations
- Financial support for training and certification of energy auditors
- Fiscal and financial incentives for investments in energy saving projects
- Framework for claiming emissions credits for investments in electricity saving (e.g. the 'White Certificates' in Italy)
- Information campaign based on the Motor Challenge Programme

Provide information and guidelines

The Joint Research Centre (JRC) of the European Commission has developed, on behalf of DG TREN, a European motor system database, called EuroDEEM²⁴⁵. This activity started in 1995 with the design of a tool for the promotion and selection of Energy Efficient Electric Motors (EEM). The scope of the database containing electric motor data is to make available an important information tool that allows users to easily carry out an evaluation of the best installation or replacement options, therefore helping to achieve electricity and money savings.

Further attention should be paid to the harmonization and dissemination of best practice examples. Information on energy efficient products should be available not only for specialist (large enterprise or public procurement) but also to SME or private user on member state level.

Research and Development

ARTEMIS (Advanced Research & Technology for Embedded Intelligence and Systems) focuses on enabling systems and components of invisible intelligence that pervade all artefacts of our everyday life - cars, home appliances, factory automation, mobile phones and practically all applications incorporating electronic functions. ARTEMIS is an initiative to reinforce the EU position as a leading worldwide player in the design, integration and supply of Embedded Computer Systems, bringing together leading industrial and academic groups across Europe.

MANUFUTURE is a technology platform on future manufacturing technologies which governs research, technology development and innovation efforts in Europe. The manufacturing industry is of great importance for the European economy, but it faces a lot of competition in the globalised marketplace. Therefore, the aim of MANUFUTURE is to provide an analysis and methodology leading to a transformation of European

²⁴⁵ EuroDEEM – The European Data Base for Efficient Electric Motors:

<http://sunbird.jrc.it/energyefficiency/eurodeem/index.htm>

manufacturing industry into a knowledge-based sector capable of competing successfully.²⁴⁶

2.2.6.2 Evaluation of existing policy options and consideration of further options

The applicability and effectiveness of the existing and already initiated policy options need a critical review in the mid-term. In order to monitor or determine the real life impact of these policy measures, statistical data on energy consumption of EuP Lot 11 products are necessary. The Lot 11 study indicated in that respect that the data situation regarding the actual energy consumption of the different product groups, stock and sales developments could be improved. We therefore suggest checking if European statistics such as EuroStat are sufficient or if the methodology to collect and assess respective data needs improvement. ICT applications may also enable metering energy consumption directly at the motor which could improve the data acquisition.

The evaluation of the existing policy options over the next years should be based on solid statistical data. The evaluation should not only determine if the expected improvement could be achieved but should provide an understanding of which measure (or combination of measures) achieved the improvement. If the improvement is lower than expected or if the situation is actually getting worse (negative development) it will be essential to adjust the existing policy instruments or even consider other policy instruments, including:

- Open method of co-ordination
- Market-based instruments
- Direct public sector financial interventions
- Co-regulation
- Prescriptive regulatory actions

However, it seems that the existing and initiated policy options are currently sufficient. As a matter of fact, the increasing price for energy (electricity) is pulling the market towards more energy efficient solutions boosting the development of new technologies and products on the supply side. A legitimate question is however if the demand side has the financial power to make necessary investments into developing or purchasing necessary technologies and products.

Technology development should focus on solving problems related to:

- ICT interoperability and control technologies related to industrial equipment (hardware and software development)
- ICT applications under specific conditions or harsh environments

²⁴⁶ MANUFUTURE: <http://www.manufuture.org/>

ICT interoperability and control technologies are essential for effective use of hybrid drives and alternative power supplies just to name two aspects. As a matter of fact there is a great need for applied research. There are many technology options from which a system designer or process engineer can choose. This decision making is difficult. Finding the right technology solution (or better technology strategy) requires interdisciplinary know-how. Particularly small and medium size enterprises do not possess this know-how. External research support is necessary for the development of a new solution and also to support the next step for progressive trouble shooting. External know-how is related to:

- Materials (e.g. how to connect an RFID on a particular metal surface),
- System integration (e.g. reliability assessments and monitoring)
- Testing (e.g. electromagnetic compatibility and respective emissions)
- Simulation (e.g. thermal management control)

ICT applications under specific conditions or harsh environments imply the improvement of electronic components, and of interconnection and packaging technologies. In order to apply ICT in industry, which implies having ICT devices in close proximity e.g. to very high or very low temperatures, changing temperatures, moist, acid, vibration, shock, and strong electromagnetic fields, conventional designs, electronic components, and micro-system, standard technologies are insufficient. For harsh environments existing solutions such as high temperature solders and substrate materials need further improvement. The respective technical development has to address not only higher temperature resistance but also the cost factor (e.g. gold containing solders are currently only available). The research topics are very specific in this field and it is not possible to cover them comprehensively in this report.

The following lists some of the research topics which could provide solutions for a more energy efficient industry:

- Research to improve ICT interoperability and control technologies related to industrial equipment
- Research to develop ICT applications for use under harsh environments
- Research to develop interdisciplinary know-how (between e.g. ICT sector and specific industrial sectors) to tackle issues linked to Materials (e.g. how to connect an RFID on a particular metal surface), System integration (e.g. reliability assessments and monitoring), Testing (e.g. electromagnetic compatibility and respective emissions), and Simulation (e.g. thermal management control)

However, these research topics need to be complemented by sector specific research requirements. For example, the textile industry has published its research priority areas²⁴⁷ in the context of the European ManuFuture Technology platform. Such

²⁴⁷ <http://www.manufuture.org/documents/manutex-def1.pdf> (May 2007)

roadmaps could be developed for other sectors of the industry, and research to identify the “priority” sectors could be initiated (statistical data on energy consumption and complete knowledge of the production chains).

2.2.7. CONCLUSIONS SUBTASK 2.2

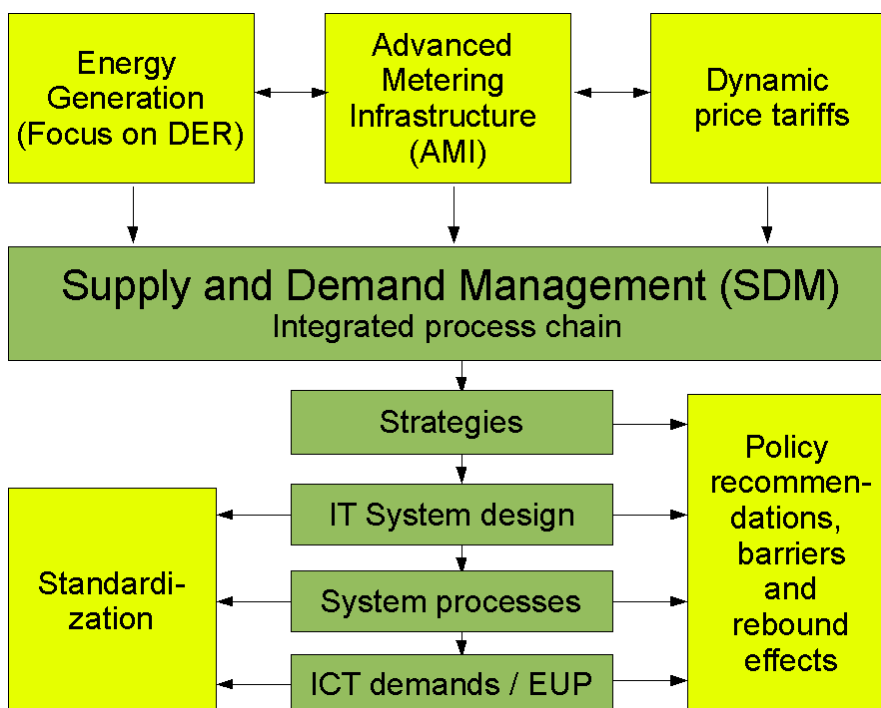
Global competition has put high pressure on costs and performance in the energy intensive industry sector, shifting production to regions with easy access to resources and labour. This implied that energy efficiency has been recognised already as an important economical factor and the industry therefore has addressed this issue in the past and improved their industrial equipment accordingly. The solutions are very specific and difficult to generalise. Trade-offs derives from particular technologies, equipment, and process know-how. This subtask showed that in the sector of final products and goods manufacturing, energy efficiency has not yet reached the highest priority and can be improved and that there is significant improvement potential. The improvement is mainly determined by the use of more efficient electrical drivers including electrical motors, pumps and fans. However, technology development will be needed as well as solid statistical data to support existing and initiated policy options.

2.3. SUBTASK 2.3: ENERGY GRIDS AND POWER DISTRIBUTION

ICT in Energy Grids and Power distribution is a very broad area. As nearly in every sector, ICT in general will be a core topic not only to enable energy saving potentials by itself but also for example to integrate different grid structures and levels in an efficient manner.

The focus of this task will be to figure out, how ICT could be used for enabling the behaviour-atomisation of applications and devices in future orientated architecture of energy system. With describing a Supply and Demand Management System (SDM-System) the focus will be on the critical path from embedding as much Distributed Energy sources as possible down to intelligent applications in households.

Figure 40: Overview of the proposed SDM System



The entire primary energy saving potential of ICT will be the result of two main effects:

- The proposed ICT based Supply and Demand Management system will enable a maximum integration of energy efficient Distributed Energy Resources like Renewable Energy and CHP plants. The result is an increase of the overall system efficiency.
- ICT integrated in each application and device of the complete process chain from energy production down to energy demand will increase the decentralized intelligence potential of the whole system. The result is a dynamic and highly flexible load shifting potential to efficient production.

In order to show a realistic view on the integration of the proposed DSM-System until 2020, only existing technologies will be taken into account. Completely new technologies like the fission and fusion reactors are out of scope. Nevertheless the calculated primary energy saving potential in the household-sector of the EU could be up to 40%”

Out of scope of this task are economical evaluations, detailed technology descriptions and special solutions for industry-processes.

A list of abbreviations used is available at the end of the subtask 2.3 document (p 247) as well as a list of the resources (p 249) and publications used (p252).

2.3.1. DESCRIPTION OF A FUTURE HIGH-EFFICIENT PROCESS CHAIN FROM HIGH EFFICIENT ENERGY PRODUCTION DOWN TO ENERGY DEMAND INCLUDING REQUIREMENTS FOR FUTURE INTELLIGENT END USER PRODUCTS

In this section the focus is on energy supply and consumer demand management as core elements of an integrated process chain. It is defined as “Supply and Demand Management” (SDM). This view is similar to other economical areas like supply chain management.

In order to understand the preconditions and the necessary enablers to SDM there is a need to discuss three subjects:

- Energy production with focus on distributed energy resources (DER)
- Advanced metering infrastructure (AMI) and assigned services
- Dynamic tariffs

At first in this study future grids are discussed, which have to be designed for a growing share of distributed energy resources (DER). This includes a look to existing researches, their goals, ICT preconditions and impacts to the supply and demand process chain.

The next subject is an overview about advanced metering infrastructure (AMI). This technology is already realized in some EU countries. Therefore AMI is described only in brief and focus on assigned services as part of the whole roadmap.

Finally an evaluation of dynamic pricing as an enabler to the SDM process chain is necessary.

The target of this process chain is to match supply and demand in the most efficient way. Supply and demand management has two main effects:

- Supply: Integration of Distributed Generation (DG), especially renewable energy resources
- Demand: Capacity to shift loads to off-peak times with different strategies

The description of the whole process chain in energy grids will require enablers and preconditions, which could be defined in the following way:

Table 109: SDM preconditions

Enabler and preconditions for supply and demand management (SDM)	DER Distribut. Energy	AMI (Smart metering)	Dynamic tariffs
Technology (ICT)	(X)	X	(X)
Consumer awareness and acceptance	-	X	X
Policy framework	X	X	X

Most technological functions of the SDM process chain are available but not yet implemented. SDM process chains have been realised up to now only in pilot projects with ICT functionality on different levels, but only in some cases with best available technology (BAT).

In order to find an adequate roadmap, processes without ICT must be integrated as intermediate solutions in this concept. AMI– best known as “Smart metering” – is such a typical technology. In a similar way dynamic tariffs, which can be realised with small ICT support, are used for a long time with different approaches. In the final step to ICT-based SDM process automation tariffs wouldn’t be required, but the intermediate use is mandatory and part of the roadmap.

2.3.1.1 Status and outlook of energy grids in Europe

The historical and current situation of the energy grid in EU-27 countries can be described in the following way:

- The existing energy grid infrastructure is mostly approx. 50 years old and is based on a hierarchical, top-down flow and distribution of power flow.
- Integration of ICT is comparatively poor.
- The existing energy grid is not designed to optimize energy efficiency, because such problems didn’t exist in the past.
- The biggest share of central power generation is still based on fossil fuel, because in the past availability, environmental impacts and costs of fossil fuels have been no topic.
- The locations of centralized power stations followed a demand structure based on heavy industries in agglomeration areas.
- The supply structure was oriented to this regional demand. The transmission grid primarily had to guarantee redundancy and to a minor extent cover load fluctuation.

We are faced with new demands nowadays and in 2020 scenarios, which must be answered now:

- The supply and infrastructure of central power plants with domestic coal and petrol in most EU countries change to natural gas. This requires an expensive gas pipeline infrastructure. To reduce the costs of the expensive gas distribution infrastructure, power plants will be constructed close to harbours and pipelines and not close to demand sides any more.
- The extension of renewable energy systems (RES) with reduced regional flexibility (like wind farms) has complicated impacts to the structure of the existing energy grids. Intermittent production of RES is a challenge to match the supply and demand of electricity in real-time at several levels of the grid. ICT process automation with

best available technology (BAT) is strongly required in this environment in order to match supply and demand based on load shifting.

- The future grid design has to enable a maximum integration of DER, because of their efficiency potentials and quick response potential to fluctuant demands.
- The understanding of energy security has changed. More and more countries and regions are facing up manmade and natural disasters. Therefore they are searching for ways to isolate energy grid disturbances and do not turn into cascading blackouts from the transmission grid.

New opportunities are:

- An exhaustive communication infrastructure is available (core telecom networks, DSL, GSM/GPRS, UMTS).
- The costs of data transfer have dropped down.
- Intelligent ICT is available within economically feasible costs.
- New household devices have already integrated ICT interfaces to remote automation.

Investments in a new infrastructure of the energy grid are overdue and would satisfy new needs without relevant additional costs on the whole life cycle.

2.3.1.2 Energy generation and distributed energy resources (DER)

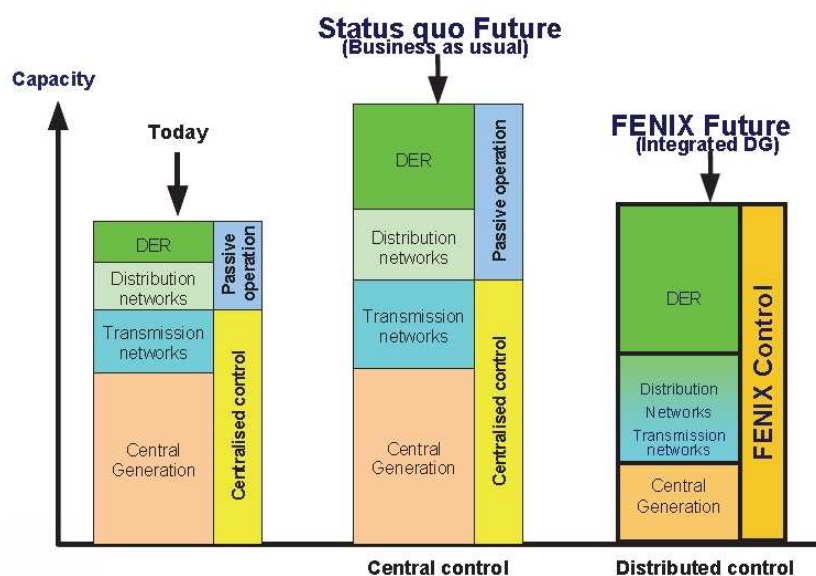
As described, the actual grid is dominated by centralised generation. On the other hand the demand side loads have a stochastic behaviour. Based on the growing part of renewable energy systems (RES) in a business-as-usual scenario in 2020, the control energy capacities have to be extended. A future grid with ICT-based optimisation could communicate with demand side loads that offer a variety of options to make the grid load predictable. These options are²⁴⁸:

- Shiftable loads
- Interruptible loads
- Loads that can be scheduled
- Highly inertial loads

Such loads can be used as “virtual energy storages”, if adequate ICT is available. This results in a more “elastic” behaviour of the whole energy infrastructure.

²⁴⁸ Haas, Ausburg, Palensky: Communication with and within Distributed Energy Resources

Figure 41: Reduction of grid capacity with BAT mirrored on BAU scenario²⁴⁹



The requirements of future energy grids in the EU will be defined until 2009 by the ongoing project FENIX (Flexible Electricity Networks to Integrate the eXpected 'energy evolution').

The following approaches are defined in this project:

- Identify network needs and the way to satisfy them using DER
- Reduce the capacity of central generation plants mirrored with a business-as-usual scenario (BAU)
- Identify potential present (and future) contribution of DER to networks that can be performed at advantageous cost
- Revise regulations, incentive mechanisms and contractual relationships between the different participants (DER, aggregators, network operators and markets), to enhance DER contribution to the network with a fair economic return
- Investigate aggregation with virtual power plants (VPP), so the limited size of DER and their non-deterministic behaviour limitations can be overcome
- Develop the ICT architecture to make it work

²⁴⁹ M. Sanchez Jimenez. "Smart Electricity Networks based on large integration of Renewable Sources and Distributed Generation. Kassel, page 74. Univ. Diss. 2006. ISBN: 978-89958-257-4. Available at internet: <http://kobra.bibliothek.uni-kassel.de/bitstream/urn:nbn:de:hebis:34-2006100414800/3/ManuelSanchez-JimenezPHDFinal2006.pdf>

The following table gives an overview of the most important changes in technical functions of energy grids, based on the required impact to decentralized power generation.

Table 110: System services and their provision today and in the future²⁵⁰

System services		Shift from transmission to distribution grid (Eco-Scenario)		
Main Topic	Task	Today (BAU)	Until 2020	Beyond 2020
Frequency stability	Primary control power (< 30s)	-	-	X
	Secondary control power (< 5 min)	-	-	X
	Minute reserve power (7-15 min)	-	X	X
Power Balancing	Scheduling and Dispatch	-	X	X
Voltage Stability	Tap changer control	X	X	X
	Reactive power control	-	-	X
Further system management	Power quality assurance	X	X	X
	Operational and asset management	X	X	X

The permanent balance between generation and consumption of electricity is an important prerequisite for stable and reliable system operation. In order to guarantee to consumers a sufficiently reliable electricity supply, transmission system operators (TSOs) keep control power available. A demand for this so-called control energy arises if the sum of actual generation differs from the actual load. Differences can arise from the load side (e.g. meteorological influences, daily load forecast error) as well as from the generation side (e.g. power station failures). The reduction of control energy is an important factor. In the European UCTE grid system the load for the first synchronous area typically varies between 150 GW and 300 GW peak.²⁵¹

The main reduction could get achieved beyond 2020 and would be out of scope in this study.

Frequency and voltage stability are hard to assess. It can be taken for granted, that a significant improvement of both these grid properties would reduce the amount of devices with battery buffer, especially uninterruptible power systems (UPS). A characteristic of UPS are energy losses, which have a macroeconomic dimension. For

²⁵⁰ Haas, Ausburg, Palensky: Communication with and within Distributed Energy Resources

²⁵¹ UCTE: Policy 1: Load-frequency Control and Performance V2.2 (final policy status), July 2004

example, a typical IT server with 400 W power consumes approx. 160 Watt only by AC/DC and DC/AC-conversion²⁵². To evaluate saving potentials, further research is required to find out the share of IT systems with UPS and acceptable conditions to dispense these systems in defined scenarios.

The integration of DER in energy grids is often discussed in the context of virtual power plant (VPP) concepts²⁵³. The evaluation of existing VPP concepts gives the following conclusions:

- The description of the VPP system is not defined precisely in existing publications. Mostly the focus is on the technical load management.
- A main feature of VPP's is the integration of control energy. This is based on a lot of decentralised sources including shiftable loads ("Negawatt"),
- VPP's are operating with a centralised control system (SCADA), which is different from the decentralised process chain described in this study.

In comparison to the SCADA, an integrated SDM process chain is much more complex and requires a totally decentralised structure with self-operating intelligent end-user products.

Another term is "microgrids", which have been the subject of an EU research project²⁵⁴. Microgrids are described as a similar scenario like VPP's with centralised control strategies, but in difference to VPP the microgrid concept has a stronger focus on the SDM process chain.²⁵⁵

■ Status and trend summary

No basic changes in the grid have occurred in the last years despite an impressive number of pilot projects concerning distributed generation and their impacts to future grids.

²⁵² <http://www.thegreengrid.org>

²⁵³ Arndt, Roon, Wagner: Virtuelle Kraftwerke, Theorie oder Realität (BWK), 2006

²⁵⁴ EU commission: Strategic research agenda for Europe's electricity networks of the future (EUR 22580) - 2007

²⁵⁵ Hatzigiorgiou, Dimeas, Tsikalakis: Management of Microgrids in Market Environment (Supported by EU research project "Microgrids"), Aug 2005

■ BAU scenario (2020)

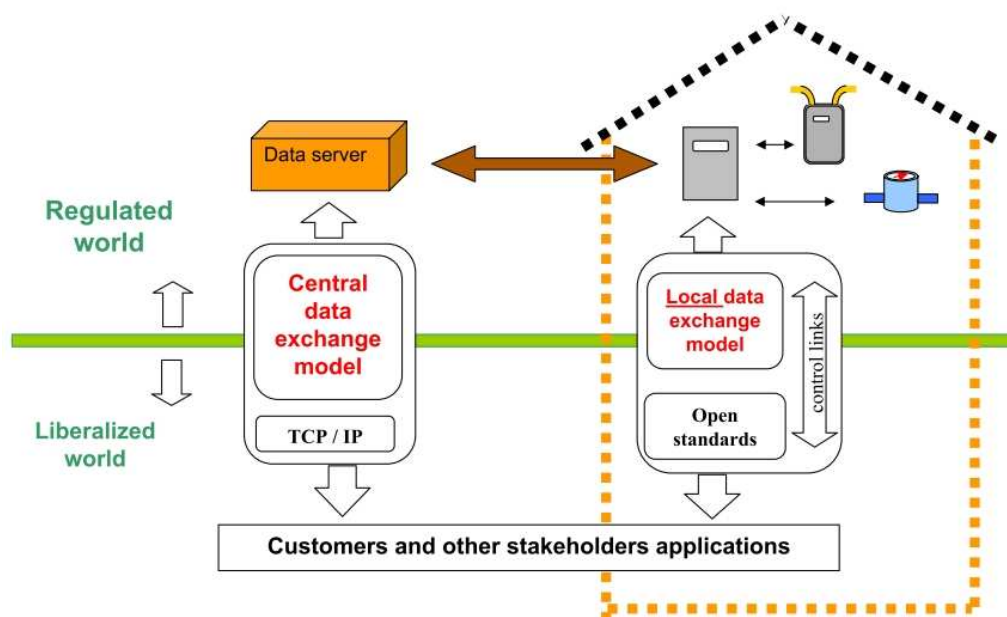
In the BAU-scenario, described in the current EU policy²⁵⁶ grid integration is not foreseeable until now. Policy recommendations would be necessary to shift to an Eco scenario.

The growing electricity consumption within Europe²⁵⁷ and the status of centralised power plants will demand investments up to 500 Billions Euro²⁵⁸ in modernization and construction upgrading anyway. A future power capacity of 376 GW is estimated²⁵⁹ compared to 740 GW capacity in 2005²⁶⁰.

2.3.1.3 Advanced metering infrastructure (AMI)

SDM process chains need not only intelligent end user devices but also a local infrastructure which is available on all demand sides. With AMI (also described as Smart Metering) a two-way communication will be possible within an additional or an integrated communication system.

Figure 42: AMI system design²⁶¹



²⁵⁶ EU commission: Action Plan for Energy Efficiency: Realising the Potential – Oct 2006

²⁵⁷ Section 1.2.1, table 2

²⁵⁸ AT Kearney press release in Vienna from 22nd Oct 2007

²⁵⁹ AT Kearney press release in Vienna from 22nd Oct 2007

²⁶⁰ DG TREN. *European Energy and Transport, Trends up to 2030, update 2007*. (2008)

²⁶¹ Andre Even: IEA seminar Smart Metering, Oct 2007

A smart-meter performs many functions like:

- Automated and remote meter reading
- Remote connection and disconnection
- Monitoring of power quality
- Consumer information about all utilities, including consumption and costs, greenhouse gas emissions, historical consumption data, current tariff and demand

Main benefits of AMI are enhanced energy data management and improved efficiency of business processes. Brochures and white papers from software supplier and consulting companies can be quoted to demonstrate the commercial interest to push AMI, for example Cap Gemini estimates that the main cost savings of AMI are:²⁶²

- Collections (15-25%)
- Standards & constructions (15-20%)
- Demand management (2-22%)
- Asset Management (4-19%)
- Load Forecasting (9-14%)

Further benefits are: Field work management, safety, metering, settlement, system control, billing and customer Care, tariff and regulatory, outage and restoration.

The typical life cycle costs of Advanced Metering in households are actually estimated to € 200²⁶³.

Based on legislative demand (**Directive on energy efficiency and energy services 2006/32/EC** (article 13)) to the calibration of meters, it is assumed, that a replacement of existing meters will be possible at least within the next 10 years in the entire EU, and that smart metering will be implemented in Europe in 2020, considering a BAU scenario.

²⁶² CapGemini (Brochure): Advanced Infrastructure Discussion, Apr 2004

²⁶³ Andre Even: IEA seminar Smart Metering, Oct 2007

■ Business opportunities of AMI

Services based on web access of metering data are opening a lot of business opportunities. For example a paid-for concierge service could analyse daily load profiles of households. These load profiles would be available with internet access and consumer accounts. Service companies could design services by identifying and localizing problems in energy efficiency continuously. An actual example in services, designed for homeowners is the Green Homes program in UK^{264, 265},

Due to the legislation agenda in Germany, metering services from independent companies (excluding grid operators and utilities suppliers) are intended but not yet realised in the next future.

Figure 43: Status AMI²⁶⁶



■ Status and trend summary

The situation in the EU-27 countries is diversified due to the lack of harmonized policy recommendations. Existing solutions are not yet based on suitable international standards.

²⁶⁴ <http://www.london.gov.uk/mayor/environment/climate-change>

²⁶⁵ <http://www.greenhomesconcierge.co.uk>

²⁶⁶ Andre Even: IEA seminar Smart Metering, Oct 2007

- BAU scenario (2020)

AMI solutions have the potential to be realized all over EU-27 countries until 2020, but with weak impact to the whole SDM process chain. Additional services with web-based access to intra-day load profiles will be enabled by market mechanisms in commercial sectors, but will need policies to be implemented to a feasible extent in households.

2.3.1.4 Dynamic Pricing

For the Supply and Demand System described in this study, dynamic pricing is a core element. Furthermore energy tariffs have an important role in order to build up consumer awareness and to enable future ICT based pricing systems.²⁶⁷

- Price models

In the next table existing dynamic price models are described.

²⁶⁷ World Bank: Primer on demand side management, Feb 2005

Table 111: Dynamic tariff models

Name of the tariff	Standing charge	Working charge	ICT demands	Remarks
"Flat Rate"	Typically low	Fixed	No	In typical household installations
Reduced Rate Off Peak	Typically higher than "Flat Rate"	Typically reduced at night time	Ripple control to switch between different tariff metering	Typically in small industries and office buildings
Time-of-Use (TOU)	Higher than standard tariffs	Variable with Day-ahead signal	Home control box or utilities website	Combination of day-ahead can be combined with reduced rate off peak
Fixed Critical Peak Pricing (CPP-F)	n/a	n/a	Day-head notification (time to response)	Project experience available from utilities in USA
Variable Critical Peak Pricing (CPP-V)	n/a	"Super-peak-prices"	"smart thermostats"	Project experience available from utilities in USA
Direct load Control (DLC)	n/a	n/a	Equipment automation to switch off with short notice	Can interrupt the electricity supply to a customer's individual appliance
Real-time pricing (RTP)	Higher than TOU tariff	Real-time	Price condition information available in AMI	User interface with price information
Virtual energy market with electronic auctions	none	Real-time	Multi-agent system (AMI / SDM process chain)	No real tariff because actual costs are based on online pricing (< 1 min)

The French supplier EDF offers a TOU tariff based on the option Tempo. This tariff is a typical combination of day-ahead prices which are combined with reduced rate off peak. Three time blocks are published in advance and combined with daytime/nighttime switch.²⁶⁸

Extensive field tests carried out in the city of Eckernförde in North Germany more than 10 years ago over a period of two years, covered approx. 1000 selected households. The purpose of this study was to develop and test a dynamic electricity tariff with clear load demand cost signals. A real time pricing system was built. An electricity price signal device with LCD-lights showed the actual electricity price at nine levels. The conclusions drawn in the report were (a) that it is indeed possible to introduce load

²⁶⁸ <http://www.tempo.tm.fr>

dependent real time pricing and (b) that such a cost oriented tariff model will be the only economically efficient pricing system on the competitive electricity market.²⁶⁹

Pilot projects in the USA were focused on a simplified approach with “Grid friendly appliances”. The field installation was made with external power plug to detect grid frequency thresholds. The restriction of this low-level demand side management is a peak-clipping strategy only.²⁷⁰

Energie Baden-Württemberg AG (EnBW) wanted to be the first utility company in Germany to offer advanced energy service to households. A time-of-use price will influence the energy use behaviour of the clients to shift from high peak time to low time periods. Together with the project partner IBM Global Business Services they developed a smart device to publish prices and to set up an automated meter infrastructure to collect consumption data.

The actual energy prices are displayed on the device - named "Energy Butler", reflecting peak and low price periods. EnBW predicts that the solution, when implemented in the pilot 2008, will give a full view on real-time pricing potential. This includes the behaviour of clients, structure of tariffs and field proven technical infrastructure to change "on demand" energy prices for residential customers.^{271 272}

Actually the standard in EU-27 countries is still the “flat rate” tariff, because a special policy with different tariffs is missing. A couple of dynamic price models were evaluated in pilot projects, especially during the last ten years. These tariff models have a growing part of ICT functionality with different level of automation and device-specific intelligence. The following ICT levels can be defined:

- Central status information in households, i.e. a LED-display with the colours red (high-price-time), yellow (middle-price time) and green (low-price time)
- AMI with more detailed information like actual load profiles and historical data
- Grid sensitive devices, which switch off in case of critical peaks, detected by grid frequency
- Remote switches as part of a direct load control (could be controlled from AMI)

Such functionalities are described in different case studies headlined with demand side management (DSM) or demand side response (DSR). In most cases ICT on the demand side is involved, but there is no intelligent ICT response. Although price models are an important enabler to a future SDM process chain, the technological impact of existing

²⁶⁹ (German) Energiestiftung Schleswig-Holstein, 1997

²⁷⁰ Roop, Fathelrahman: Modelling Electricity Contract Choice (PNNL), Aug 2004

²⁷¹ IBM press release Feb 2008

²⁷² Frey: Preissignal an der Steckdose (EnBW), Oct 2007

ICT from such price models to future demands is poor, unless an AMI is installed. The benefit to future demands is user awareness and capacity building to overcome existing barriers.

Dynamic pricing with best available technology is not only a subject of real-time processes. Additional long term processes are also part of the whole process chain. Real-time decisions from electronic agents may be controlled by operator on the supply or demand side.

Pricing is embedded in a lot of business processes. The following table gives an overview about such processes.

Table 112: Dynamic tariffs and assigned processes

Time frame / range ahead	Participants (Operator)		Supply and demand process chain
	Suppliers	Demands	
Year	Budget planning	Detection of Benchmarks	Energy management strategy
Month	Operational planning, billing	Billing from supplier with real costs	Operational energy controlling
Day-ahead	Schedule of generation	Schedule of device operation	Supply-demand strategy based on weather-forecast and expected availability of renewable energy resources
Intra-day	Emergency program, Load reserve capacity	Schedule of device operation	Operation scheduling of Interruptible devices
< 15 min	Control energy capacity (ICT automation only)	Direct load control (ICT automation only)	Automatic load shifting
< 1 min	Electronic auctioning (ICT automation only)		Multi-utilities supply and demand chain

■ Status and trend summary

A lot of pilot projects with dynamic pricing models already exist in Europe and North America. These projects are based on proprietary ICT with different levels from weak grid-frequency sensors to real-time price sensitive appliances. Policies to enhance the standardised use of existing dynamic tariffs are missing.

■ BAU Scenario (2020)

Although dynamic pricing models will become a big share based on the use of AMI, as far as they are available and installed, the optional use of existing dynamic tariffs is missing in the BAU 2020 scenario.

2.3.1.5 Supply and demand management (SDM) process chain

With the SDM process chain approach the existing descriptions do not fit the requirements and opportunities of future grids. SDM defines a process chain, which could lead to a completely decentralised energy infrastructure. This is different from current definitions, which are based on hierarchy. The most common definition of demand side management (DSM) is based on the centralised structure with one supplier of utilities and a big number of demand sides. In the future, supply and demand could be bi-directional. The functionality of supply and demand can change due to requirements of single processes. Furthermore the SDM concept fits not only supply and demand processes with utilities, but could be in the same way fit to other process chains with flexible supply and demand.

The main efficiency potential of dynamic demand scenarios is the load shifting potential. The resulting benefits are considerable and include:

- A more stable electricity grid
- Enabling a higher proportion of renewable energies in the system due to a optimized supply and demand matching
- A cost reduction of integrating renewable energy
- Businesses opportunities based on ICT applications
- Reduced central power capacity

The following examples are describing the different impacts of SDM strategies:

Example A: An electric heat pump can be utilized for energy management on the consumer side to reduce costs. In order to realise energy efficiency potentials on the system level, electricity has to be produced with better efficiency than a central power station with an overall efficiency of primary energy source of typically 30 – 35 %. Only if the needed electrical energy is produced by renewable resources or high efficient CHP systems the energy saving potential is relevant.

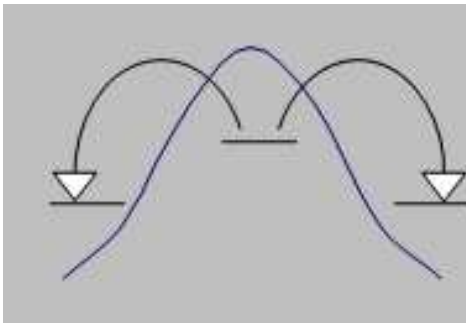
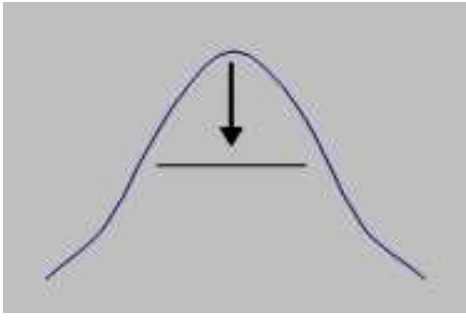
Example B: The operational requirement of a washing machine is to deliver clean clothes. This is embedded in a scheduled process chain with follow-up activities, like e.g. the transfer to a dryer machine or a manual drying process. The starting time is typically stochastic from the energy generation view. Shifting such kind of operations to off-peak periods can reduce the required less efficient peak load capacity of the system. Therefore energy efficiency will be improved on the system level, although the energy consumption of the consumer is still the same.

Example C: A change from fuel driven automobiles to electrical drives would be a significant increase of electricity consumption. If the battery recharge is managed to happen in peak-off times and assumed that electricity is coming from renewable resources, the energy efficiency of the whole system can be enhanced.

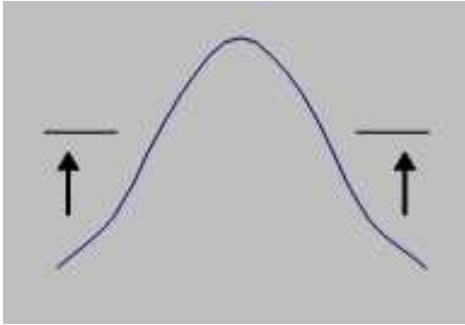
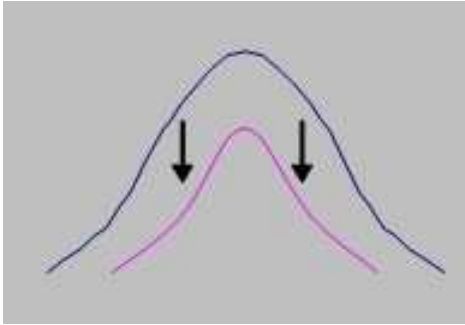
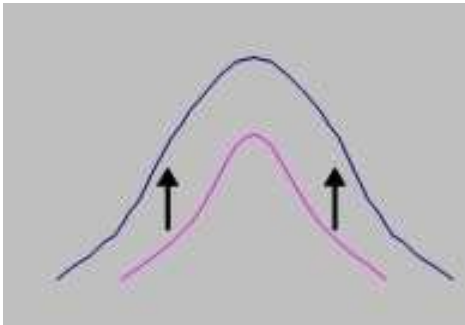
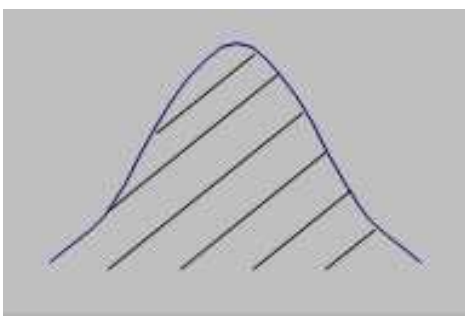
■ General Strategies in Supply-Demand Matching

The following section (Figure 44) describes six strategies, which were fixed in research and confirmed in several sources to be useful. However these strategies use the view of demand side behaviour and don't fit all supplier strategies, which are described later.

Figure 44: Demand side management strategies²⁷³

	<p><u>Load Shifting:</u></p> <p>This method moves loads to off-peak times. Normally the switch-off time is restricted to several minutes and based on functional demands, like keeping temperature without fixed upper and lower limits. This method is used in automation systems with load control programmes, if the system is capable to handle the functional restrictions.</p> <p>Examples: Devices with storable cooling or heating energy, like refrigerators, freezing machines (→ Example 1)</p>
	<p><u>Peak Clipping:</u></p> <p>This method interrupts devices regardless of inconvenience or process demands. This method is mostly used in automation systems with load control programmes. Different from load shifting the energy consumption is not shifted to off-peak times. Therefore the result is also an energy saving effect, but the overall reduction of consumption is mostly small.</p> <p>Examples: Air conditioning and electrical heating systems (→ Example 3)</p>

²⁷³ (German) Bundesminister für Wirtschaft und Technologie: Potenziale der Informations- und Kommunikations-Technologien zur Optimierung der Energieversorgung und des Energieverbrauchs (eEnergy), Dec 2006

	<p><u>Valley Filling:</u></p> <p>If neither a load shifting nor a peak clipping are suitable for a device or the operator, this method is necessary. Times of operation must be moved by ICT support to a load valley. Grid load can be scheduled from the operator based on time limits, when the operational result must be available.</p> <p>Examples: washing machine, dishwasher, battery charger (→ Example 2)</p>
	<p><u>Strategic Conservation:</u></p> <p>This strategy defines overall reduction of electricity consumption as a result of energy efficiency actions. This strategy has a strong ICT impact, but requires manpower and user awareness to reach this goal.</p> <p>Examples: Reduced consumption of energy to lighting, which is typically a mixture of different actions, like the installation of energy saving bulbs, reduction of operation times (automatically or based on user awareness)</p>
	<p><u>Strategic Load Growth:</u></p> <p>In special cases electrification could have an impact to save energy loads based on fuels with CO₂ output.</p> <p>Examples: Electric vehicles can be supplied based on photovoltaic power generation, which is (at least partly) stored in batteries and delivers power to plug-in “filling stations” for vehicles.</p>
	<p><u>Flexible Load Shape:</u></p> <p>Peak times are created from whole processes. A flexible load shape means a push of whole processes to different times.</p> <p>Examples: Daily peaks between 6 p.m. and 8 p.m. in Central Europe are caused from typical households with children. Single or couple households could be flexible and move their load-consuming household activities to times after 8 p.m., because of more individual life style.</p>

Peak Clipping, Valley Filling and Load Shifting are strategies of load management and require ICT-procedures. Since a long time such procedures are in use in industry and commercial buildings. Typically these procedures are part of software functions in industrial process automation and building management systems.

Strategic conservation is the result of energy efficiency actions and could be based on a strong ICT impact, but also on manpower and user awareness. As far as ICT automation is required, these technologies exist and have a market-driven consumer approach. This strategy is out of scope in this study.

A strategic change from private car transports to electric cars would have a complicated impact as a strategic load growth combined with fuel driven cars in private transportation. In terms of SDM strategies this would be a combination of Strategic load growth and Valley filling. Although this change would have a strong effect in energy efficiency, car transportation is out of scope in this study. An additional study will be required to research all impacts including environmental sustainability²⁷⁴

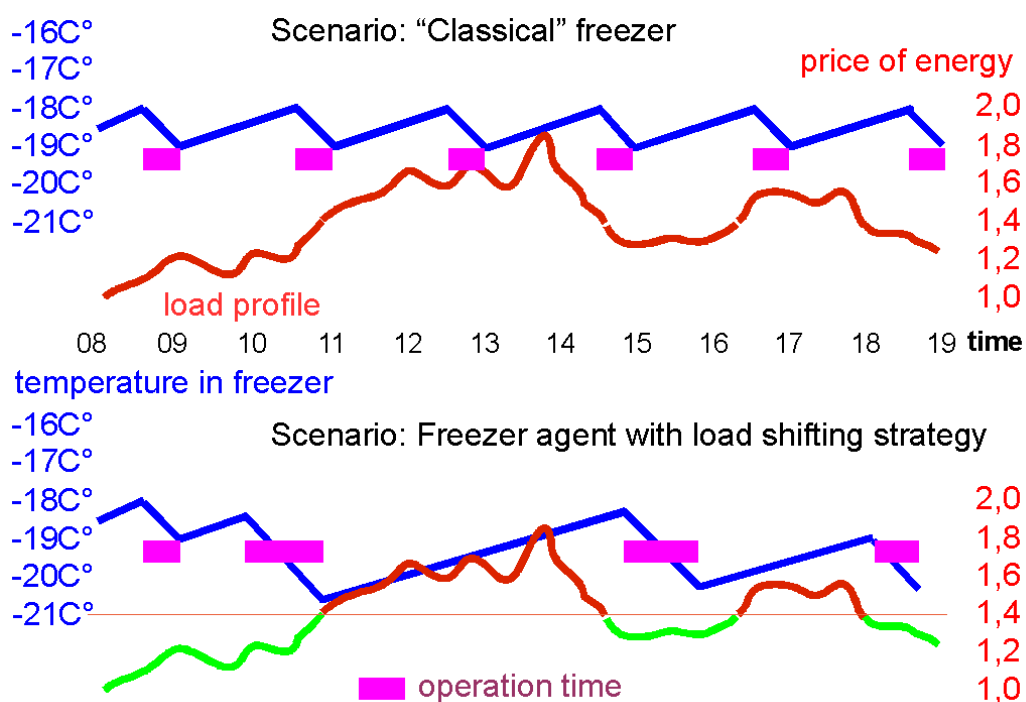
■ Strategy example 1

The compressor of a freezer will operate by a classical two-point control with fixed temperature limits. The thermostat indicates the switch on-off times. Although this operation appears very regular, we have a stochastic behaviour from the supplier view.

With a device agent the control system will be influenced to move the switch points to higher or lower temperature, which wouldn't touch the proper function of the freezer. The total operation time and energy consumption would be still the same, but the freezer has enhanced (non-stochastic) switch-cycles. The freezer is switched off on peak load times, as far as possible (!) within the extended temperature range.

²⁷⁴ EU 21384: The future impact of ICTs on environmental sustainability, Aug 2004

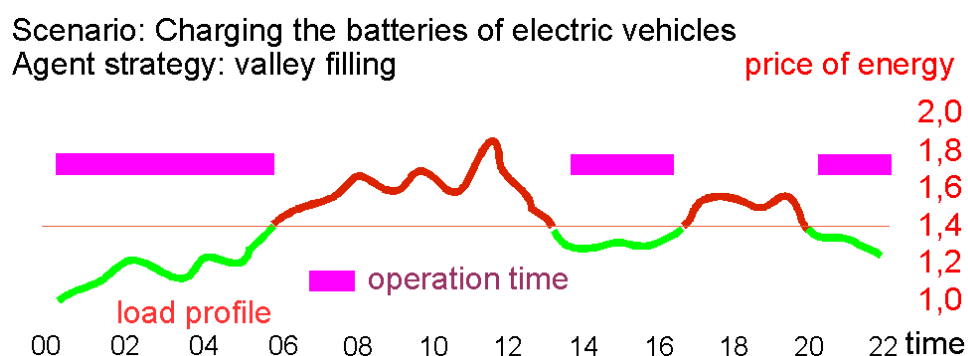
Figure 45: Load shifting example²⁷⁵



■ Strategy example 2

Different from the first example we have no process constraint in the operation time. The battery charging is operating with full flexibility in off-peak times.

Figure 46: Valley filling example²⁷⁶



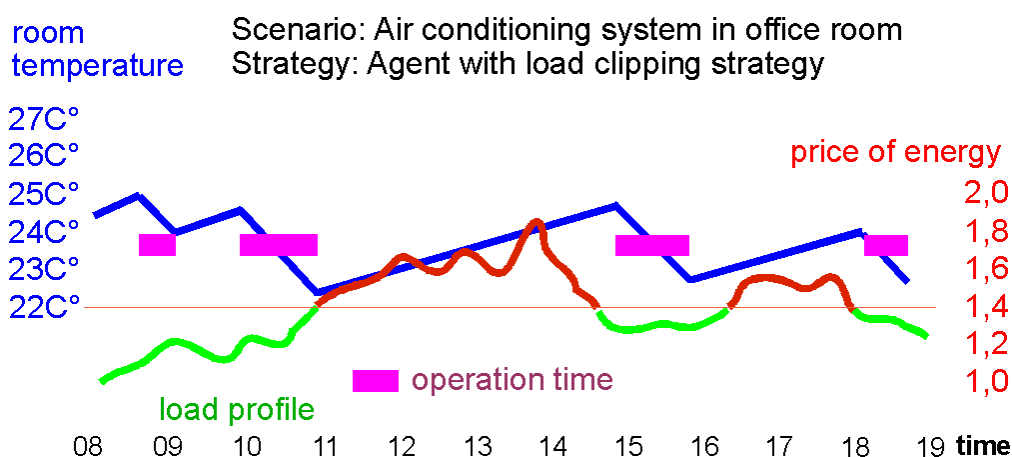
²⁷⁵ UfE GmbH (edited from e5)

²⁷⁶ UfE GmbH (edited from e5)

■ Strategy example 3

Although this example appears similar to the curves in example 1, the constraints make a basic difference. The air conditioning device is interrupted regardless of inconvenience for consumer. Of course the increased room temperature based on the device switch-off must be acceptable. Different from the load shifting strategy in example 1 the energy consumption is not necessarily shifted to off-peak times. If reduced air conditioning is used late in an office room, the user may have left the room when off-peak time comes back. Therefore the result is also an energy saving effect, but the overall reduction of consumption is mostly small.

Figure 47: Peak clipping example²⁷⁷



2.3.1.6 SDM system design

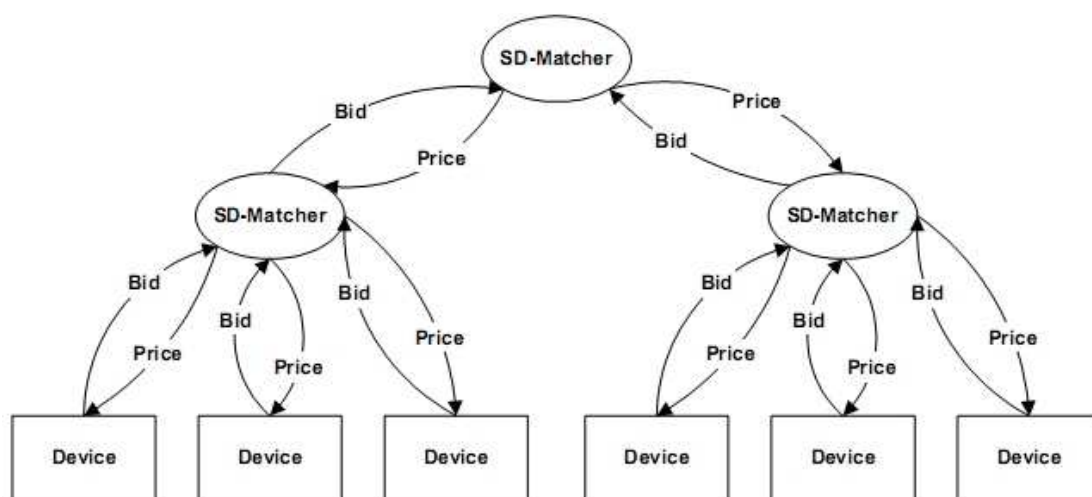
A future grid with ICT automation has to handle a growing share of distributed generation (DER) and a decentralized matching of supply and demand. In a decentralized grid the following functions have to be realized autonomously:

- Simple forecasting of supply capabilities and expected demand
- Economic scheduling (priority list and useful sequences)
- Security assessment (supply: availability based on historic emergency cases and operation times, demand side: constraints from processes)
- Load curtailment (strategies in supply-demand-matching)
- Single devices in this process chain have to make price-sensitive decisions in real-time.

²⁷⁷ UfE GmbH (edited from e5)

At least the load shifting and valley filling strategy require intelligent devices, which build up their own strategy to react on real-time price condition information. In theory each device requires a software agent as supply-demand matcher, which gets price information and participates in an electronic virtual market with its own biddings. In this subsection a multi-agent system (MAS) is described, which is able to calculate the best real-time behaviour autonomously.^{278 279 280}

Figure 48: Hierarchy of supply & demand matchers in the PowerMatcher concept



The SD-Matchers implement a distributed electronic market²⁸¹. The basic behaviour of these agents is following market policies with two different basic approaches:

1. Agents are serving the needs of their own demand only, requesting no reactive supply from the grid.
2. Agents are buying and selling active and reactive power to the grid supporting their operations.

In the first case the agent tries to minimize the energy costs for the whole energy grid. In the second case the agent tries to maximize the value of the energy grid, maximizing the profit from the power exchange with the grid. In both cases, the active and reactive power is considered.

²⁷⁸ ECN:Massive coordination of dispersed using powermatcher based software agents (Presentation)19th International Conference on Electricity Distribution Vienna, May 2007

²⁷⁹ Malik: Modelling and economic analysis of DSM programs in generation planning (International Journal of Electrical Power & Energy Systems), Jun 2000

²⁸⁰ Oyarzabal, Jimeno, Engler, Hardt, Ruela:Agent based Microgrid Management System (Supported by EU research project "Microgrids"), Aug 2005

²⁸¹ ECN:Massive coordination of dispersed using powermatcher based software agents (Presentation)19th International Conference on Electricity Distribution Vienna, May 2007

Along with the SD-matcher concept an electronic market can be established. The latest research has identified the following five types of device agents:

Table 113: Types of multi agent devices²⁸²

Device category/ Purpose	Sources		Description	Examples
	Supply	Demand		
Stochastic operation device (Strategy: not available)	X	X	The output power of these devices cannot be controlled. Device agents must accept any market price. This type also includes user-action devices, whose operation is a direct result of a user action.	Generator: PV-system and wind farm Load: domestic devices like audio, video, computer, lighting
Shiftable operation device (Strategy: valley filling)		X	Batch-type devices whose operation is shiftable within certain limits. Processes that need to run for a certain amount of time regardless of the exact moment.	Domestic washing machines, ventilation systems in utility buildings
External resource buffering device (Strategy: load shifting and valley filling)	X	X	Devices that produce other resources than electricity, that is subject to some kind of buffering. Mainly heating and cooling/freezing processes, which keep a temperature within certain limits.	Electrical heating or Air conditioning systems, generators like CHP's
Electricity storage device (Strategy: load shifting and valley filling)	(X)	X	A bi-directional connection to the grid allows the strategy to buy energy at low prices and sell it later at high prices.	Conventional batteries or advanced technologies like flywheels or super-capacitors
Freely controllable device (Strategy: load shifting, peak clipping and valley filling)	X		Devices that are controllable within certain limits. The agent bidding strategy is closely related to the marginal costs of the electricity production.	Diesel generators, CHP's in electrical peak load operation mode

The result on the system level is a self-interested behaviour of local agents, which causes electricity consumption to shift towards moments of low electricity prices and production towards moments of high prices. The merge of supply and demand matching can be seen on the global system level as improved energy efficiency.

²⁸² Kamphuis, Kok, Warmer, Hommelberg: Massive coordination of residential embedded electricity generation and demand response using the PowerMatcher approach (Energy Research Centre of the Netherlands), Jan 2007

In all described device categories, agent bidding strategies are aimed at carrying out the specific process of the device in an economically optimal way, but within constraints given by the operator.

■ Virtual energy markets and electronic auctions

A future real-time pricing can't be restricted to the electrical grid environment. Future grid concepts have to be assigned not only to electricity grids but also to district heating systems. Future district heating systems could be based on decentralized micro-CHP systems, which deliver heat for local use, but could also supply buildings in the neighbourhood. A real-time price electricity tariff wouldn't fit such a complex optimisation. The described multi-agent system is necessary to find a multi-utility optimisation.^{283 284}

Although energy market mechanisms are not in the focus of this study, we have to consider about virtual energy markets based on electronic auctions, in order to realise an optimal control of DER. Especially the behaviour of optimized CHP's will be most complex in this environment, including:

- Storage capacity of heating energy
- Marginal costs of electricity production to satisfy peak loads
- Matching the technical switch-off cycle in operation
- React to stochastic DER (wind farm, PV-systems)
- React to supply shortage because of single unit operational blackouts

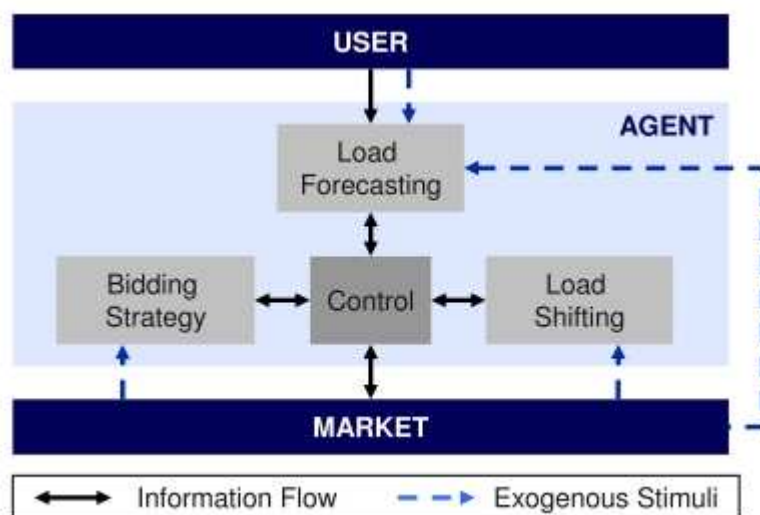
Energy agents have to accomplish the following tasks in order to profit from optimised energy costs based on energy auctions:

- Forecast of future energy demands
- Weather forecast concerning assigned renewable DER and energy costs to expect
- Acquire energy for different time slots from different markets to meet the predicted demand
- Supervise success rate of bids placed in different markets

²⁸³ Deindl, Block, Vahidov, Neumann: Load Shifting Agents for Automated Demand Side Management in Micro Energy Grids – Working Paper -(Institute of Information Systems and Management University Karlsruhe), Mar 2008

²⁸⁴ Wernstedt: Multi Agent Systems in District Heating Systems (Blekinge Institute of Technology Sweden), Nov 2005

Figure 49: Trader agent scheme²⁸⁵



■ Status and trend summary

Up to now we have a theoretical approach to an integrated SDM process chain, which is based on first concepts published 10 years ago. Existing concepts have evaluated all impacts like the integration of all kinds of distributed generation, multi utilities and different strategies to match supply and demand. ICT with economic costs based on calculated mass production is available. Existing research is still fragmented and ICT standardization is still poor, because of the missing links between distributed generation, AMI, appliances and dynamic pricing.

■ BAU scenario (2020)

A SDM process will not be realised until 2020, if policy recommendations are missing. Without this, no market-driven realisation can be expected. Only the public awareness of the opportunities will develop.

2.3.2. EVALUATION OF EFFICIENCY POTENTIALS WITHIN THE PROCESS CHAIN

The main primary energy saving effects of the proposed SDM system are resulting out of the load shifting effect.

■ Basic assumptions

As general assumption, the live style and household income in the entire EU in 2020 will be levelled out on a status that is comparable with the living standard in Germany of the year 2005. Due to this, the estimated load shifting potential per household in

²⁸⁵ Deindl, Block, Vahidov, Neumann: Load Shifting Agents for Automated Demand Side Management in Micro Energy Grids – Working Paper -(Institute of Information Systems and Management University Karlsruhe), Mar 2008

the entire EU in 2020 could be assumed as the same potential already found out for German households in 2005²⁸⁶.

A second general assumption has been made by calculating for 2020 with already best available technology to produce energy out of fossil fuels. In order not to overestimate the saving potentials due to SDM, on the one hand for an average control energy power plant in 2020, a BAT 2005 control energy plant has been taken into account. On the other hand, the average fossil fuel driven Distributed Energy Plant of the year 2020 is assumed as the BAT Combined Heat and Power Plant already existing.

Further assumptions for calculating the energy saving effect are:

The BAU scenario 2020 has been assumed with:

- Smart-metering implemented
- No SDM integration of DER besides restricted regional projects
- No price-sensitive intelligent appliances in households
- SD-Matching potential

The Eco scenario 2020 has been assumed with:

- EU area-wide integration of SDM potential which enables the shifting potential
- Household devices implemented broadly over the entire EU with intermediate ICT and controlling system based on AMI abilities and dynamic tariffs
 - Calculation of load shifting share
- The electricity requirement of German households in 2005 was 138,4 TWh²⁸⁷ and will see a 10%²⁸⁸ increase to 152 TWh in 2020
- Due to the implemented SDM system a load shifting potential of 72 kWh/month²⁸⁹ per household can be realised
- The number of German households in 2005 was 39,8 Million²⁹⁰

²⁸⁶ Klobosa, Erge, Bukvic-Schäfer, Hollmann: Demand Side Management in dezentral geführten Verteilnetzen - Erfahrungen und Perspektiven (11th Kasseler Symposium Energy Systems Technology), Oct 2006

²⁸⁷ Klobosa, Erge, Bukvic-Schäfer, Hollmann: Demand Side Management in dezentral geführten Verteilnetzen - Erfahrungen und Perspektiven (11th Kasseler Symposium Energy Systems Technology), Oct 2006

²⁸⁸ (German) VDE-Studie: Dezentrale Energieversorgung 2020, Jun 2007

²⁸⁹ Klobosa, Erge, Bukvic-Schäfer, Hollmann: Demand Side Management in dezentral geführten Verteilnetzen - Erfahrungen und Perspektiven (11th Kasseler Symposium Energy Systems Technology), Oct 2006

2020 load shifting potential German households in TWh²⁹¹/a:
72 kWh/month x 12 month x 39.8 Million households = 34.4 TWh/a (I)

Load shifting potential as share of consumption:
34.4 TWh^(I) /152 TWh = 22.6% (II)

- EU-25 consumption and saving potential
- The electricity requirement of the EU25 in the residential (household) sector in the year 2020 will be 1097,5 TWh²⁹²
- The load shifting potential of electricity demand in the residential sector, shifted from inefficient electricity production periods to efficient electricity production periods is 22,6%(II)

2020 effective energy shifting potential EU-25 households in TWh/a:
1097.5 TWh x 22.6 %^(II) = 248 TWh electric energy (III)

What has been calculated so far could not be seen as an energy saving potential. To come to the real saving potential in TWh we need a primary energy approach. Primary energy is the entire energy in the fuel to be used to produce effective energy like electricity.

The SDM system will enable to shift electricity production from inefficient power plants to efficient power plants where less non-renewable-primary-energy like fossil fuel (natural gas) is used.

In order to calculate the amount of primary energy which could be saved with the SDM system by enabling the load shifting potential, the production efficiency of different power plants has to be taken into account.

- As average control energy power plant in 2020 a BAT 2005 (Best Available Technology) gas turbine plant with a production efficiency of 35%²⁹³ will be used for calculation (control power (power to leverage the fluctuating load of e.g. wind turbines and PV) mainly comes out of gas turbines).

²⁹⁰ EUROSTAT : http://www.eds-destatis.de/en/downloads/sif/nk_03_24.pdf

²⁹¹ Terra-Watt-hours, 1 TWh =1000*1000 MWh

²⁹² This study chapter 1.2.1 Table 2

²⁹³ (German) BINE Informationsdienst, basis Energie17 – Effiziente Kraftwerke, Mai 2004

- As efficient and fast DER plant an efficient Combined-Heat-and-Power-plant with a production efficiency of 90%²⁹⁴ will be used for calculation.

Primary energy used to produce 248 TWh^(III) in gas turbine
248 TWh / 35% = 708.6 TWh primary energy (IV)

Primary energy used to produce 248 TWh^(III) in CHP-plant
248 TWh / 90% = 275.6 TWh primary energy (V)

Now the basis for calculating the real energy saving potential of the proposed SDM system has been prepared. To find it out, the primary energy, used in the CHP-plant (V) has to be deducted from the primary energy, used in the gas-turbine (IV).

Primary energy saving potential due to SDM-system:
708.6 TWh^(IV) - 275.6 TWh^(V) = 433 TWh per year

Moreover, it is estimated that each kWh of electricity produced by means of CHP saves between 0.07 – 0.32 kg CO₂ per kWh (all savings attributed to electricity)²⁹⁵ compared to a kWh produced by the European grid. Savings in terms of CO₂ eq. emissions can therefore be calculated and are estimated between **17.36 and 79.36 Mt CO₂ eq.** (According to (III) the 2020 effective energy shifting potential EU-25 households is 248 TWh electric energy which is equal to 248,000,000,000 kWh, further:
 248 000 000 000 x 0.07 = 17.36 Mt CO₂ and 248,000,000,000 x 0.32 = 79.36 Mt CO₂)

2.3.2.1 Description of barriers

The major barriers, identified to realise the above mentioned energy saving potential are not missing R&D results, pilot projects, missing ICT devices and components but:

- Lack of consumer demand on AMI and very little engagement of users in end-use innovation activities resulting in low acceptance and missing “killer” applications
- No EU-wide mass implementation of AMI
- No real-time efficiency-oriented pricing
- No harmonised standards
- Unbalanced power (in terms of influence) structure of energy market actors

²⁹⁴ (German) ASUE: BHKW-Kenndaten 2005

²⁹⁵ ECOFYS. Low Carbon Electricity systems, Methodology and Results for the EU (2003)
http://assets.panda.org/downloads/wwf_powerswitch_scenario_eu.pdf

- General global unified standard production of end-devices. Regional new developed features are not seen as mandatory SDM-requirements
- Broadband internet connection is not yet a general primary requirement for each household (last meter issue) but a pre-requisite for the EU-wide SDM implementation
- The present ownership of infrastructure is not supporting fast implementation tracks
- Shortage of ICT experts within the energy sector
- Shortage of SME liquidity and investment support. New business and investment models and commercialisation support of successful finished R&D projects, and pilot projects is needed.
- Efficient regulatory support to harmonize the European energy market
 - Educate and Empower the Consumer - The lack of consumer demand

Three approaches have typically been used to encourage people to change their energy-using behaviour:

- information, e.g. publications, websites, energy information centres, energy audits, energy labelling of appliances, equipment and buildings
- pricing, e.g. inclining block tariffs, and time-varying pricing, such as time of use (TOU), critical peak pricing (CPP), real-time pricing (RTP)
- regulation, e.g. minimum energy efficiency performance standards (MEPS) for appliances, equipment and buildings

The effectiveness of the three approaches has been variable:

- information alone has generally been not very effective
- effectiveness of pricing is variable; better results are achieved when combined with an information campaign and perception of some sort of “energy crisis”; behavioural response may reduce over time
- regulation has been quite effective, but it forces behaviour change rather than encouraging long-term attitudinal change; complete market transformation is required for maximum effect

The lack of consumer demand is also a factor that can explain the delay in the roll-out of innovative ICT products or the reluctance to develop eEnergy applications. There is generally a lack of awareness among individual users of the benefits and opportunities of ICT in private life. More compelling products and service platforms for the mass market are needed in order to increase general public interest.

Learning’s from broadband services indicate that the lack of uptake of new innovative digital broadband services is mostly the result of a lack of skills rather than a problem

of broadband availability. The Dutch Presidency (2004), in its report “Rethinking the European ICT Agenda”, suggested that there should be a shift from “access to all” to “skills for all”. Enhanced skills and motivation would in turn increase demand and hence lead to more investment and service roll-out. This is word by word true for AMI and other eEnergy services.

Following recommendations can be made to encourage people to change their energy-using behaviour:

- Develop the economic and public policy rationale for greater consumer participation in the marketplace. Restructuring has already created competition on the supply side. However, lack of comparable mechanisms on the demand side means that consumers do not receive timely price signals, resulting in over-consumption at peak times and over-investment in peaking resources. Lack of price signals also leads to arbitrary standards for energy efficiency. Demand-response mechanisms must be integrated into a market transformation if it is to be successful.
- Ensure the capital investment required to create the “energy/information portal” to the home or business. Private investment can be justified by downstream market opportunities. Public investment can be justified by advantages the portal will enable—more efficient use of resources, price moderation and energy efficiency created by real-time pricing, and the creation of new retail service businesses.
- Increase the opportunity for service differentiation for various classes of consumers. Many power consumers—especially commercial and industrial customers—would prefer a choice of service contracts that are differentiated by quality or price. Quality options may range from premium, digital-standard power to agreements on curtailments or interruptions. Price options might range from real-time “spot” pricing to long-term contracts. Other options could be based on load profiling, peak-load pricing, curtailment at a cut off price, cycling, or dispatch ability of a load.
- Engage the consumer in end-use innovation. The opportunities to fundamentally improve both service value and energy efficiency ultimately require greater consumer engagement in electricity markets. Until consumers and innovators have open access to each other through a functionally enhanced power delivery system, lack of progress and a restrictive regulatory structure will remain a self-fulfilling prophecy. Only through establishment of the energy/information portal can retail service differentiation eventually be taken inside the home and business, linking consumers and even microprocessor-enabled appliances directly with innovative service providers.

■ Standardisation

Standardisation of equipment and systems is mandatory:

- Information systems must be fully compatible,
- Network must be open for all manufacturers,

- Metering must be uniform, but do not prohibit innovation,
- Plug and Play enabling Standards
- Interfaces and functionality have to be standardises,
- Supply quality must be standardised
- Standardisation of roles and responsibilities in the grid operational practice
 - Open Standards and Interoperability

Implementing and managing the SDM requires an “ecosystem” approach, where technology vendors collaborate using open standards to deliver an open, secure, cost-effective and intelligent technology infrastructure comprised of:

- Smart grid devices that are always on-line, via
- Reliable, high-speed, high-bandwidth, secure telecommunications networking, so that distribution automation, demand management, and other energy services are provisioned, delivered, consumed and analyzed rapidly and efficiently, and
- Centrally managed via policy networking (or business rules driven) software and protocols, to ensure consistent, cost-effective and adaptive energy service delivery
 - Open application solutions

The SDM-System requires truly open application solutions. The optimal technology for implementing and managing the SDM-System should be:

- Built on open standards and protocols, so that utilities can choose the most innovative and cost effective solutions, and avoid “single vendor, proprietary product lock-in” seen in other solutions
- High performing and scalable, in order to cost-effectively manage tens of millions of customer energy service delivery points, meters, and other distribution automation devices
- Integrated, interoperable and optimized, to leverage innovations from all technology and product providers, the Smart Grid solution ecosystem of vendors, customers, and standards groups
- Resilient and adaptive, so that the SDM can self-heal points of failure, or provision new services rapidly and cost-effectively — self-healing, self-provisioning, and self-optimizing
- Secure and reliable, so that SDM devices and services are well protected, and meet both governmental and industry SDM security specifications, guidelines, and recommendations

SDM Network Management software solutions should provide a truly open, proven, scalable, extensible, secure, policy-based network management system for the SDM.

A service-oriented architecture should be easily integrated with enterprise systems via standards-based interfaces, reducing complexity, cost, and time to deployment.

Support for heterogeneous networks should be provided via extensible plug-in layer architecture, providing a common service interface for utility metering.

■ Software

Software offers should offer a number of key advantages, including:

- Efficient SDM management that drives lower network capital and operational expenses needs software for central management to ensure efficiency and productivity via the software-based automation of a utility's business, operations, and networking rules (or policies), but also fully distributed intelligence, and rich features and capabilities at the point of delivery, enabling utilities to deploy and manage advanced energy services directly to their customers.
- End-to-end, truly open architecture for adaptive, ongoing innovation and integration. Some vendors claim to be open but they are not.
- Open architecture ensures that utilities can take advantage of ongoing technology innovations, avoid proprietary vendor "product lock in", and create best-of-breed SDM solutions that ensure the lowest possible operating costs in both the short- and long-term.
- Highly secure, reliable, scalable, powerful software platform.

Related platforms should leverage the investments in advanced network security from the telecommunications industry to deliver industrial-grade, government certified security to each aspect of the utility SDM based on networking technology and protocols currently used in real-world Internet operations proven to scale reliably to millions of networked devices.

International Electrotechnical Commission (IEC) — working groups that are focused on advanced metering, and information exchange among interoperable systems supporting business functions for the smart grid

Internet Engineering Task Force (IETF) — working groups focused on advanced network and application-level security, and policy-based networking technologies and protocols

WiMAX Forum — to promote and accelerate cost-effective broadband wireless access services into the marketplace, enabling economies of scale that, in turn, drive price and performance levels unachievable by proprietary approaches

HomePlug Powerline Alliance — to enable and promote the rapid availability, adoption and implementation of cost effective, interoperable, and standards-based home powerline networks and products

■ Interoperability, software and infrastructure lifetime

Interoperability is another important topic linked to ICT applications in energy systems. The industry remains primarily responsible for delivering technical interoperability to meet market needs, and technical interoperability has advanced considerably in recent years. At the same time, concerns about fragmented national energy markets also continue to increase. The legal, semantic, and organisational interoperability issues that exist in Europe have a more direct impact on the differing levels of ICT uptake in this region vis-à-vis the rest of the world. Differences between EU Member States in regulatory requirements have slowed the widespread usage of some technologies (for example AMI). Lack of agreement on semantic data requirements, and organisational differences between administrations, have hindered the uptake of available technology that could improve productivity and created obstacles to the roll-out and take up of services.

These aspects become even more important if they are linked with very long expected lifetimes of grid infrastructures and different investment cycles of ITC including software and infrastructure.

It is essential to start thinking about software in a way more sustainable way: the software systems should last for generations without total rebuilding. This requires new thinking and new ways of organising development. This is especially important for governments of all sizes as well as for established, ongoing businesses and institutions.

There is still much to be built and maintain in terms of software applications. The number of applications for software is endless and continues to grow with every advance in hardware for sensors, actuators, communications, storage, and speed. Outages and switchovers are very disruptive. Having every part of society need to be upgraded on a yearly or even tri-yearly basis is not feasible.

Dan Bricklin is stating: “Let us look at the needs for societal infrastructure software. They include the following:

- Meet the functional requirements of the task.
- Robustness and long-term stability and security.
- Transparency to determine when changes are needed and that undesired functions are not being performed.
- Verifiable trustworthiness of all three of the above.
- Ease and low cost of training for effective use.
- Ease and low cost of maintenance.
- Minimisation of maintenance.
- Ease and low cost of modification.
- Ease of replacement.

- Compatibility and ease of integration with other applications.
- Long-term availability of individuals able to train, maintain, modify, determine need for changes, etc.

The structure and culture of a typical pre-packaged software company is not attuned to the needs of societal infrastructure software. The "ongoing business entity" and "new version" mentality downplay the value of the needs of societal infrastructure software and are sometimes at odds."

The future Energy Web needs a kind of "basic societal infrastructure software" to generate modest lifetime cost over e.g. 40 years.

■ Security

In distributed system architectures, apart from a standardized communication for the exchange of operational and trading data, one requires security of communication for reasons of data privacy, authenticity, and for protection against sabotage²⁹⁶. Security flaws are introduced accidentally due to the unavoidable interfaces between private and public (i.e. the Internet) network infrastructures. Thus, there is a necessity for fire-walls and encryption both symmetrical and asymmetrical to guarantee tamper-proof operation of the system.

The problem with closed source security implementations is the danger of remaining security holes, often leading effectively to a "security-byobscurity" situation, instead of real security. With open source implementations one has the advantage of auditing by a large community. Contrary, when security flaws are revealed, the infrastructure is temporarily at risk²⁹⁷.

In opposite to the IT world where the awareness of security is given on a wide scale due to the various attacks and threats to networked computers in the last years this awareness is not strengthened in the area of field bus systems and automation. The main reasons for neglecting security issues in such systems are that they were often used within closed environments (e.g., in industry automation), and security threats from the inside were not considered, and that the protocol should be kept as efficient as possible to allow execution on very small microcontrollers.

For the future energy system the situation is - maybe with the exception of application servers which are located in trusted environments of the utility companies - different: the main system components like Access Points, Bridges, Nodes and Meters are installed at customers' premises or directly in the field (e.g., in a non-guarded

²⁹⁶ Power system control and associated communications – Data and communication security, IEC TR 62210, Stefanini A (2005) The future of ICT for power systems: Emerging security challenges. Report of the workshop held in Brussels

²⁹⁷ Distributed Power Generation: Requirements and Recommendations for an ICT Architecture, Ludger Winkels, Oldenburg, Germany

transformer station). Also the PLC communication network is publicly accessible and cannot be controlled to protect against eavesdropping, manipulation and distortion. The IP-based network will most likely also use public networks like or leased lines due to cost effectiveness. The situation becomes even worse if public IP networks are involved.

A threat analysis points out that many of the system components are target to malicious assaults. The data transported by the network includes valuable data directly related to costs for the customers like meter readings.

Hence the following basic security goals must be integral part of the system:

- confidentiality, meaning that only authorized entities must be able to read confidential data,
- integrity, stating that no unauthorized entity must be able to change data without being detected,
- authorization, defining that only authorized entities must be able to generate data,
- availability, mandating that data is at hand when needed,

Analysis of the above goals indicated that integrity and authorization are important goals, whereas confidentiality should be scalable and is not needed in all applications.

The main challenges for the security system will be the performance characteristic of PLC system like packet size, data rate and packet loss and the insecure location of equipment in the field. Last but not least cost restrictions must be considered, because energy meters must after all be cost effective²⁹⁸.

■ Interrupted supply of electricity

In order to remain competitive, firms in all western industrial countries must computerise their manufacturing processes. The level of automation has constantly increased and become more efficient. A stable secure mode of operation of PLC (Programmable Logistic Controllers) and PC systems is dependant on a top quality power supply. Critical processes are therefore dependant on a UPS (Uninterruptible power supply) because even the shortest power cut can have fatal effects on the process. There will be rejects and the machine will possibly be damaged if half-finished products get stuck in it. The more sophisticated the automation the more the process depends on an uninterrupted supply of electricity. Complicated networks used to control lighting, blinds, air conditioning, and entry and security systems in buildings also all depend on a continuous supply of electricity. Here too centralised UPS systems which keep at least the essential processes going are increasingly being used.

²⁹⁸ Real-time Energy Management over Power-lines and Internet, Albert Treytl, 'Institute of Computer Technology, Vienna University of Technology, Vienna, Austria, 2006

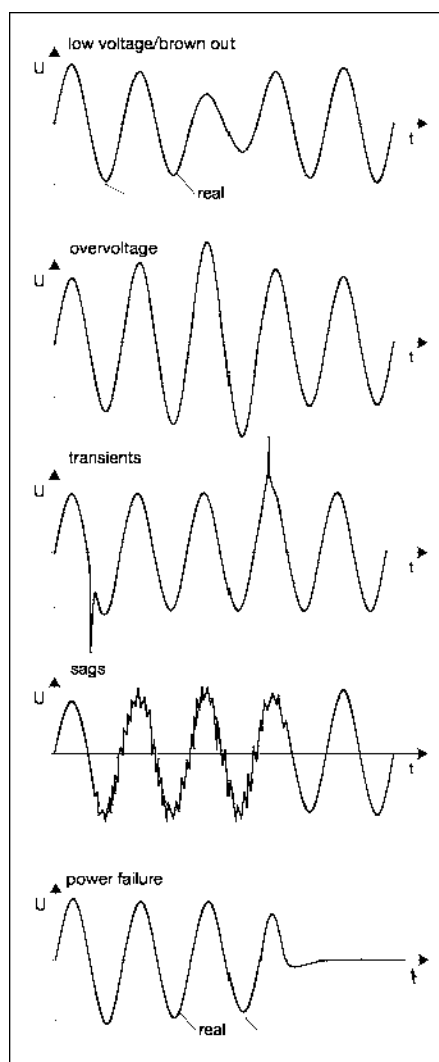
■ The consequences of a computer crash

It is surprising to see how careless even large firms are in securing a reliable supply of utility power. They should know how much the success of a company is dependant upon it. A power failure of only some few minutes may have fatal consequences such as:

- Loss of image
- Loss of contracts
- Loss of a customer
- Breakdown of customer service
- Backlog in production
- Loss of operational data

Before the deregulation of the electricity market, experts warned of difficult times ahead in terms of availability and quality of electrical energy. Their predictions have proved correct here in Europe more quickly than we would have liked. The requirements of the digital world have increased dramatically in the last two decades with regard to the availability and quality of electrical energy. There is a growing imbalance between the need for stable electrical energy and the situation as we have it on the energy market. A disquieting prospect – not for the manufacturers of UPS units though! They can reckon on a growing demand for their products

Figure 50: Frequent faults in the utility power²⁹⁹



■ Typical problems in the utility power network

Problems are not only caused by power failures. Short interruptions that do not even cause a light bulb to flicker can have treacherous consequences for different sorts of equipment. In computers, network components and telecommunication systems, overvoltage can cause the electronics to become defective. Hidden effects are the most treacherous. In such cases a sensitive electronic device still functions but its power consumption rises, leading to overheating of the element and finally to failure.

Figure 50 shows the typical problems in utility power.

- Low voltage (brown out)

²⁹⁹ The Digital World and Electrical Power Supply- A Hypersensitive Imbalance, GE Consumer & Industrial Power Protection, 2007

Approximately 60% of the disruptions. This is the most frequent problem and is usually caused by large consumers of electrical power, not by the user or the supplier.

- Over-voltage

Approximately 20% of the disruptions. It stems from switching operations performed by large consumers and can lead to hardware failure.

- Transients

Approximately 8% of the disruptions. Transients (spikes) are extremely short occurrences of over-voltage. They can be several times higher than the rated voltage and get through the power supply units to the equipment, causing faulty transmission of data or leading to hardware failure.

- Sags

These considerably distort the ideal sine waves of the utility power. The consequences can be 'inexplicable' system failures or faulty transmission of data. These problems are caused by pieces of equipment that do not draw a cleanly sinusoidal current (light controllers with phase shifting control utility power command guiding systems).

- Power failure

It is common to distinguish between those failures lasting milliseconds and those lasting minutes or hours. The latter are much less frequent in Northern Europe than the former. Every UPS system must be able to cope with both types of power failure.

Saving potentials with stable and secure grids are essential. To illustrate this, take the example of a large network with approximately 200 computers, including the monitors, printers and other network components, all of which are dependant on a UPS for their energy supply. Let's assume that the network is used for 12 hours per day. For this network a UPS supplying 100 kVA is necessary. At full utilisation and assuming 3% less degree in efficiency there is an additional loss of power of 3 kW. Assuming further that these 3 kW are lost for 12 hours during 365 days per year – which is unrealistically high – the additional 1000 €, if one kWh costs 0.10 €. This then would be the amount saved by choosing a grid with perfect stability.

Further research also in context of EuP and SDM stability is needed.

A unique and sizeable DG and DR potential is emerging due to the proliferation of enterprise-class Data Centres (base load of one MW or more) in a digital society. The extreme high power densities and sizeable power magnitude (to exceed 2.5% of

national grid in five years)³⁰⁰ promise significant benefits through intelligent management. There may be several opportunities for intelligent integration with, and perhaps control of, data centres to enable demand reduction, demand optimization, power profile optimization, distributed generation, emergency power sourcing, and other schemes

2.3.3. DESCRIPTION OF THE ICT DEMAND AND REQUIREMENTS OF EACH ELEMENT OF THE PROCESS CHAIN

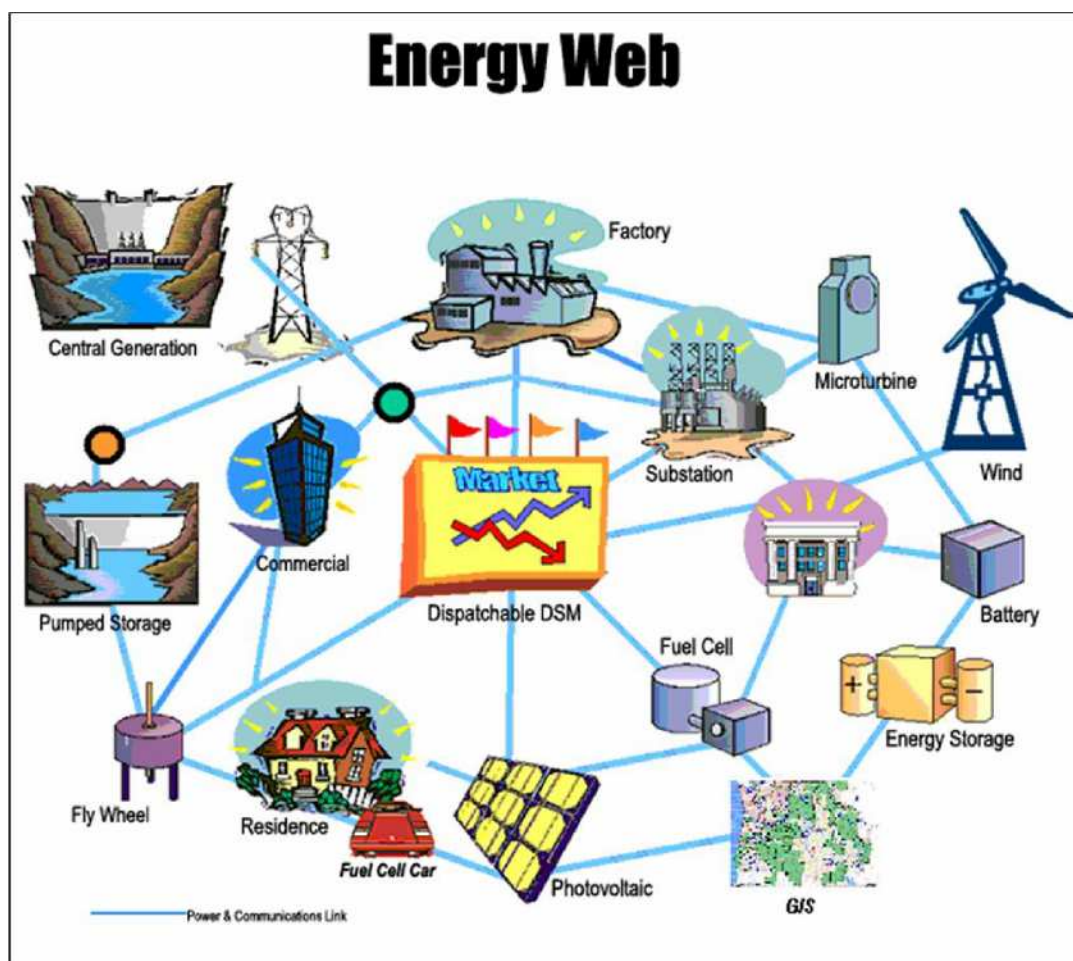
Information Society Technologies (EU-IST) program for Research and Technology Development Provides a long term vision of where distributed intelligence will go (as a coherent bundle of advanced ICTs) over the next ten to twenty years:

- Step 1: Internet plus World Wide Web: To be considered as universally available baseline infrastructure
- Step 2: Pervasive and Ubiquitous computing: Each device will have built-in computing and communication power. Computer itself becomes "invisible" analogy to electro motors.
- Step 3: Ambient intelligence: Local intelligence plus global communication. Semantic Web: from data hyperlinks to web of meanings (ontology's). Intelligent Agents: decentralized large-scale processing, decision, control.
- Step 4: From IS to Information "eco" Systems: Info organizations of collaborating humans and systems. Intelligence in IS: systems that are aware of user context. IS: socio-economic context aspects must be factored in.

Because more devices for customer generation and storage of energy will be in operation in the future, the customer - residential, commercial, or industrial - will be considered a vital part of the electrical power systems of the future.

³⁰⁰ Standardizing the Classification of Intelligence Levels and Performance of Electricity Supply Chains, NEMA, 2007

Figure 51: The Energy WEB³⁰¹



The tasks of ICT span from sensory acquisition of consumption data up to databases, energy services to global, distributed control of distributed energy resources (DER).

The ICT has built up its experience and know how in the field of energy and IT over the recent years in a row of international and national research and development projects.

■ Real-time Energy Management

Example: REMPLI- Real-time Energy Management³⁰² via power lines and internet

The REMPLI system provides a real time collection and control system for the energy distribution and consumption, using power lines and Internet for communication, and enabling tasks like balancing energy delivered to and consumed out of the energy network, energy management for supplying companies, energy management on the consumer side and energy billing. Part of the ICT commitment to this FP5 EU project is the implementation of security in the low and high bandwidth sections.

³⁰¹ Bonneville Power Administration, www.bpa.gov

³⁰² <http://www.rempli.org/>

■ Visualisation

Example: JEVIS- Java Envidatec³⁰³ Visualisation

The core of the JEVIS system is a powerful database that is responsible for storing and managing SCADA data. Customers connect to an Internet portal, authenticate themselves and use the services offered by the database system. These services include, for instance, graphical visualization and analysis of measured energy consumption, statistical calculations and also benchmarking. The ICT focus in this project, which was conducted with the industry partner Envidatec GmbH (Hamburg), lies on the integration of different technologies, protocols and products via abstract interfaces to the database as well as the goal to keep system complexity as low as possible.

■ Resource Optimization

Example: IRON- Integral Resource Optimization Network

IRON³⁰⁴ aims to improve the efficiency of the power grid by means of an integrated communication infrastructure that allows for coordinating and optimizing the consumption schedules in the network. By conducting coordinated demand side management, flexibilities in consumption processes and distributed storages in the grid can be facilitated. Concepts like real-time demand response on energy pricing, virtual power plants or provision of imbalance energy enable to integrate the operation of the IRON already within the current regulatory framework. After IRON Study, this ICT-initiated national research project conducted together with an Austrian transmission grid operator and other partners from industry and academia, is now in its second stage, IRON Concept, which is planned to be followed by the field test project IRON Pilot.

■ Demonstration Network

Example: DG DemoNet³⁰⁵- Distributed Generation Demonstration Network
The main goal of the DG DemoNet Concept project is to analyze the possibilities for implementing different technical solutions for enabling a very high DG penetration of the medium and/or high voltage grid. The project demonstrates how active operation of distribution networks can be realized based on innovative solutions as model for future electricity networks. Like in the IRON project, an actual field installation is planned for a second project stage. This national research project is led by arsenal research. The project consortium consists of research institutions and transmission grid operators. The ICT is active in the area of communication technologies for DG

³⁰³ <http://www.envidatec.com/templates/home.php?sprache=4&sproj=1>

³⁰⁴ http://publik.tuwien.ac.at/files/pub-et_9556.pdf

³⁰⁵ <http://www.demo-net.org/>

coordination as well as supporting the algorithmic approaches for coordinated voltage control.

2.3.3.1 Assessments of liquidity and business opportunities in the market

Liquidity situation in the sector is good, but unevenly distributed. All this places the burden of technological and financial risk mostly on the shoulders of SMEs.

To date, Europe leads the electricity manufacturing industry (ABB and Siemens are world leaders) but EU companies are already operating and investing at the global level. In turn, foreign investors have started to invest in EU. International cooperation is current practice (e.g. with US and Japan), but more cooperation is needed on standardisation and normalisation.

There are some small-scale demonstration projects ongoing in Europe (e.g. in Germany, Greece, Denmark, Spain), testing different schemes for the networks of the future; however there are several technical and engineering barriers in quickly developing and implementing large scale projects.

Large deployment of intelligent distributed generation and demand/response programs will require consistent business models, economy remaining the main driver for distributed generation. A number of existing projects including BUSMOD and EU-DEEP cited above are already studying those issues, and such efforts should be continued. Future business models will be influenced by power market rules, which have yet to be studied given their low level of maturity. Finally, little data exist about social acceptance and sociological aspects of “peer-to-peer energy” systems. These systems will require the development of new services and products, which will need to be assessed on non-technical aspects such as their acceptance (is the product/service “ethical”?), their value to the user (is it useful?), their ergonomics (is it easy to understand, use and integrate into the user environment?), their economical value (how much the user is willing to pay for such product/service?). Again, field tests and pilot implementations will be required to assess these issues.

■ Smart Energy Business Opportunities

“Smart Energy Opportunities. Think Globally, Profit Locally” was a conference title of the AeA Conference in March 2008 in Seattle/ US.

The conference title is reflecting the need to lead the global market.

U.S. is leading the charge. A new project has been announced to deliver the first ever Smart Grid City³⁰⁶ that will be a “first step toward building the grid of the future,” according to Dick Kelly, Xcel Energy chairman, president and CEO. “In Boulder, we’ll collaborate with others to integrate all aspects of our smart grid vision and evaluate

³⁰⁶ <http://www.renewableenergyworld.com/rea/news/story?id=51845>

the benefits. The work we're doing will benefit not only Boulder, but also customers throughout our eight-state service territory."

In addition, the GridWise Alliance³⁰⁷ (including CISCO, GE, IBM, SAP and others) aims to drive forward an "electric system that integrates the infrastructure, processes, devices, information and market structure so that energy can be generated, distributed and consumed more efficiently and cost effectively; thereby achieving a more resilient, secure and reliable energy system," according to its website. Founded in 2003, the Alliance is an advocate for change on both the national and state levels. Its members include utilities, IT companies, equipment vendors and new technology providers.

The International Energy Agency (IEA)³⁰⁸ has said that more than US \$16 trillion will be spent worldwide between 2003 and 2030 in pursuit of the Smart Grid vision. To date, several projects have been announced with large organizations like Iberdrola³⁰⁹ and EDP [<http://www.edp.pt>] supporting the charge. Iberdrola has been working extensively on the definition and testing of new open, public and non-proprietary telecom architecture to support not only AMI functionality but also to progress towards the electricity networks of the future.

EDP has launched its InovGrid³¹⁰, an innovative initiative that aims to implement an "intelligent grid" during the next few years, through a new systems, communications and technological infrastructure that will integrate commercial and metering processes, network automation and management, and also control of distributed energy resources and micro-generation in Europe.

More recently an announcement has come out of Ireland³¹¹. The Electric Supply Board said it will spend €4 billion of the funding on renewable-energy projects and €6.5 billion to support AMI and smart-grid networks. The funding is part of €22 billion in investments the utility plans to make through 2020 to reach a goal of delivering one-third of its electricity from renewable sources.

Over the last few weeks announcements from ZigBee, Pepco, Gazprom, Siemens and eMeter have also been released relating to AMI projects indicating the wealth of interest in the space over the last 6 months.

³⁰⁷ <http://www.gridwise.org/>

³⁰⁸ <http://www.iea.org/>

³⁰⁹ <http://www.iberdrola.es/>

³¹⁰ <http://www.edp.pt/EDPI/Internet/PT/Group/Media/EDPNews/2007/InovGrid.htm>

³¹¹ <http://www.greentechmedia.com/articles/funding-roundup-will-green-investments-bring-ireland-more-luck-743.html>

2.3.3.2 Assessments of the use of applications as enabler of behaviour change

Technical solutions must help the citizen to reduce consumption and to facilitate behavioural change. To do this the following is needed:

- Demand side partnerships
- Smart meters to empower customers to improve energy efficiency in home and workplaces
- Provide economic and behavioural incentives to educate the energy user
- Empowering citizens to generate local power from local energy waste sources

2.3.3.3 Possible issues related to SDM implementation

The most obvious identified issues are:

- The smart meter that is seen as a key entity for the future smart grid, will be a distributed one, composed of many real and virtual units e.g. at home, at the car, or even embedded as part of every electrical device and bound to the user which have to be functional cross boarder and in a harmonised environment. Recognising the regional and national SDM implementations this is a major challenge for EU legislators, and standardisation bodies.
- Data protection/privacy must be guaranteed in AMI and MAS as the proposed ITC based energy system could be a target for hackers and terrorist.
- Loosing interoperability, software upgradeability in the context of long infrastructure lifetime in opposite to the “likely service-time” and “time to be in business” of many SME’s in the ICT sector.
- Increased energy demand due to the ICT use in SDM-Systems. However, the energy demand for ICT components in SDM is assumed to be negligible compared to the total Energy savings through SDM.
- Development of major proprietary solutions from market leaders will reduce or prevent innovation for other innovative market actors in this sector
- The cost involved in buying the proper AMI devices and intelligent end-user devices could lead to a social end-user divide analogue the Digital Divide
- The lack of social acceptance for electricity infrastructures (in particular networks).
- The shortage of qualified workforce in the EU. In the past the electricity sector has benefited from large know-how and skilled technicians. Today more electrical engineers and qualified labour are needed.
- More collaboration and simplified cooperation guidelines between different stakeholders should be produced to enhance EU research output. Whilst in the past long term planning was performed, now the electricity system actors are looking primarily at the short term profit

2.3.4. DESCRIPTION OF GENERAL POLICY RECOMMENDATIONS

As already stated earlier, the liquidity situation in the sector is good, but unevenly distributed. All this places the burden of technological and financial risk mostly on the shoulders of SMEs. The appropriate policy response to this structural challenge should be a combination of stick and carrot, that is, policies which:

- Continue policy efforts towards a common European energy market
 - Promote “fair” pricing based on the use of non-renewable/renewable energy
 - Stimulate and fund R&D and innovation equal in all stages of clean energy production and commercialisation
 - Enhance Innovation and R&D collaboration of large companies in the sector with national and international research actors and dynamic SME’s within renewable- and eco- technologies supported by innovative ICT solutions realised in European production
 - Pay much more attention on public/ consumer awareness and capacity building on energy issues because this is an underestimated factor which could shape the future economic and technological trajectory in the sector.
- Market-based policies

What political leaders and regulators do at this point in our transition to the competitive market will be critical to the future success of that market.

Well-intended but short-sighted consumer “protections” such as price caps, or other interventions, must not be allowed to interfere with the achievement of a diverse and sustainable competitive electricity market. Fluctuating market prices should not be viewed as a failure of deregulation. Electricity prices in particular can be extremely volatile at times, mirroring the volatility in electric demand. Energy policymakers must recognize that it is those very prices that send a clear signal to plant developers to invest in more generation capacity. In energy markets, as in most commodity markets, high short-term prices are often the best cure for high long-term prices.

For electricity markets to work efficiently, retail consumers must be allowed to see true price signals, just as generators and retail suppliers see them in the wholesale market. We must recognise that the creation of multi-year rate freezes stifles competition for retail electric sales, and prevents these customers from knowing the true costs of their electricity consumption.

Given that the vast majority of electric customers receive service at cost-capped rates; this has become an increasingly significant problem. European policymakers need to address this issue if we are to continue to enjoy the benefits of electric competition in the long-term.

A final recommendation is that the Commission policy includes a strong endorsement of the benefits of competition over regulation, and a firm statement that market-oriented restructuring remains the best opportunity we have to provide a reliable and affordable supply of electric power.

■ Regulatory framework

The existing non harmonised regulatory framework vested in National laws and codes. The current market structure and regulatory context should be modified to manage the transition towards the future electricity network architecture like the proposed SDM-System. More common rules (e.g. on the network development incentive mechanisms) should be defined for the management of all the ICT components of the electricity system.

There is a need for active incentives for transforming the networks and a more energy-efficiency friendly framework. It is recommended to develop a clear perspective for infrastructure ownership.

Legislation is a key-enabling factor for the adoption of intelligent distributed generation, as laws still exclude some of the schemes considered at the research level (e.g. trading one's production on a local electricity market). The absence of both a clear structure definition and field tests regarding these micro generation systems does not (yet) allow such legislation to be developed.

- The regulatory framework has to be supportive for real customer energy services (Power to the people). The regulatory framework should open customer access to other service providers to enable differentiation and segmentation of customer groups versus cost of services (e.g. power quality) and business opportunities.
- The regulatory framework also should deal with the risk of splitting the society into advanced and less advanced users (similar to the Digital Divide) and support energy-related investments in homes.
- The regulatory framework should enable new mandatory intelligent end-user device requirements pushing global mass-production of them.
- The regulatory framework also should establish a tied data security framework ensuring privacy and preventing data risk in the proposed SDM- System.

■ Research

Under the pre-condition of market liberalisation, the existence of future harmonised standards, clear long-term policy stability, and of harmonised legal framework implementations of governments and of the Commission, the resulting business potential is so enormous, that free market mechanism is projected to provide the necessary capital and create all necessary ICT technologies at the right time in the right volume. Business needs to create powerful marketing activities towards the consumers to get acceptance of technology and services offered.

The new 7th Framework Programme for Research (2007-2013) has initiated a research funding area on "ICT for Energy Efficiency" activities to support RTD on the next generation of ICT contributing to sustainable growth, which is initially focusing on production processes and services, monitoring and control of power grids and energy neutral buildings. So far, a total of 11 projects are under negotiation for a global budget of approx. €32 million, with €22 million Commission support. Reported lessons learned are:

- in general, a very good response to all topics addressed in the Work Programme, which shows the actual relevance of the topic and the readiness of main ICT and energy actors to cooperate in this sector.
- good coverage of innovative ICT solutions for drastically decreasing the energy consumption of end-users, especially on novel control and power demand balancing systems at distribution and local level.

All necessary research is enabled. However, the open harmonised market for implementation and long-term investment security is missing. A focus could be put on creating the right framework conditions such as:

- making usage of Metering and Billing (real consumption) mandatory in Europe
- creating large scale penetration of Smart Metering to reach 100% penetration in 2020
- investigating the opportunity for setting up a publicly available infrastructure for smart metering (versus PLC and GPRS)
- pushing standardisation groups : Open standards for interoperability across the value chain
- promoting the advancement of commercial PHEV (Plug-in Hybrid Electric Vehicle)
- promoting renewable energy programs around cars
- pushing the creation of time of use rate plans as incentive for PHEV
- changing the regulatory framework to allow pan-European ubiquitous micro-payments; apply this to the SEPA (Single Euro Payments Area)

Also, current RTD efforts should continue in the following areas:

- distributed generation, including micro-generation, with a focus on capacity and load management/balancing demand-response.
- intelligent integrated energy management systems in buildings.
- improving the energy efficiency of components, products and services.
- intelligent metering as a gateway to Energy Efficiency Services.
- management of complex power system.
- energy consumption visualisation in homes and buildings.

- advanced high-efficient power electronics for Distributed Generation.
- policy research for promoting consumer behaviour. This is including Development of Advanced Customer Value Added Services based on Smart Metering and Customer Communications
- a real-time pan-European ubiquitous micro-/mini- billing infrastructure. Existing systems e.g. mobile payments, GeldKarte etc could be seen as the first steps. The infrastructure should of course include security, archiving, invoicing, signing and verifying of invoices, real-time payments, cross-channel support etc.

■ Innovation

Innovation is important, for achieving all policy aims (cleaner energy production, safe energy supply and cheap energy supply) in the energy production sector. However it is a recurrent theme that innovation does not thrive in markets with very low degree of competition. Creating competition over national and sectoral borders in the energy market is the key enabler for innovation in the global market competition.

The level of innovative firms in the energy sector (even in large firms) is low. The finding of the INNOVA Project³¹² is confirming the evidence that R&D expenditure and R&D output such as patents are also lower in the energy sector compared with the rest of the economy.

More than 60 % of the innovative firms in the energy sector are classified as technology modifiers and technology adopters. The four different modes of innovation in question include strategic innovators, intermittent innovators, technology modifiers, technology adopters. A small number of firms are classified as strategic innovators.

The implication of this finding is that the dominant mode of innovation in the energy production sector is an incremental one, with innovation activities only partly developed in-house or adopted by others and without involving R&D activities. This means that research policies do not directly address the needs of the sector and that policies on increasing demand of high-skills, policies stimulating technology and knowledge diffusion, investments in training and capital investments may be adequate policy targets for improving innovation performance and innovation efficiency in the sector. A particular emphasis must be given to innovation activities taking place in firms and sectors from which the energy production sector is adopting knowledge.

The main structural innovation challenge is that the sector consists of large incumbents with considerable financial power and of small new firm entries struggling to survive in new market niches.

³¹² <http://www.europe-innova.org/index.jsp?type=page&lg=en&from=child&classificationId=9333&classificationName=Reports%20of%20the%204th%20Set%20of%20Innovation%20Panels&cid=9334&parentClassificationId=4962&parentClassificationName=Innovation%20Panels&parentContentId=5089>

The main challenges related to skills in the sector seems to be the low number of younger employees, the low number of women employed in the sector and the shortage of ICT experts as well as other technical personnel which could facilitate innovation processes in the sector. Provided that innovation processes depends on this type of expertise in large energy utilities, innovation policy should prioritize the issue of skills needs in the sector in a more coherent manner.

The ICT technologies should be more considered as disruptive technologies revolutionising the complete energy system than as incremental improvement of existing technologies.

The primary objectives of innovation policy for this sector should be:

- Coordination with other policies to create incentives enhancing ICT- and eco-innovations among the energy process chain.
- To enhance ICT product- and process-innovations among actors and to stimulate commercialisation of promising technological solutions.
- Focus on energy infrastructural needs, in particular how to develop a flexible pan European ICT supported power grid allowing the implementation of the proposed system.

This is also true for EU non-R&D innovation support programs.

EU Member States will need to spend around 390 b€ in network infrastructures over the next three decades (some 90 b€ for transmission and 300 b€ for distribution networks); a 30% share is planned to come from public funding.

As a benchmark, the investment estimated by the American GridWise council to modernize the US transmission & distribution grids amounts to 450 b\$³¹³.

Power System networks have design life-cycles in excess of 40 years. In order to meet the European policy goals the need for urgent and immediate action to apply innovative solutions and appropriate policy frameworks is pressing. Needed technology is already available. In most cases existing technology can enable the changes needed. However other barriers still exist.

- Link to automotive sector electric and hybrid cars

The SDM-System could be also seen as an enabler for the next generation of automotive vehicles. Car manufacturers will benefit from having an integrated, simple and cost efficient charging solution for customers with electric cars.

³¹³ Summary Report on the Hearing of the Smartgrids Energy Technology Platform, European Commission: RALDOW W. (Chair), Petten, June 2007

2.3.5. CONCLUSIONS SUBTASK 2.3

The analysis shows that in an optimistic scenario, the implementation of a Supply and Demand Management (SDM) system could save the equivalent of 433 TWh of primary energy in 2020, compared to a business-as-usual situation (BAU). This is equivalent to 37.2 Mtoe and would represent 2.3 % of the projected BAU primary energy consumption in EU 27 for the year 2020³¹⁴ (this result can be put in perspective with the EU primary energy reduction target of 20% through energy efficiency)³¹⁵.

The estimated 37.2 Mtoe saved through the implementation of an SDM system are equivalent to the amount of primary energy required to produce 148 TWh³¹⁶ of electricity which could represent 3.7 % of the projected total EU-27 electricity consumption in 2020³¹⁷.

The main findings can be summarised as following:

- Stronger demand to introduce AMI as an enabler.

Example: In Germany AMI is still not mandatory despite new regulations made in June 2008.

- Real-time efficiency-oriented pricing should be mandatory based on existing AMI.
- A master plan to change the energy use of people in households should be predefined from the EC, based on corresponding suggestions in this study.
- Existing standards in AMI are far from harmonised. More pressure/ directions from EU policy are necessary.
- SDM requirements are based on an overall availability of data communication infrastructure like DSL, GSM/GPRS or UMTS. Up to now the telecommunication provider can't deliver a 100% supply of the whole population. In order to make an ICT infrastructure mandatory as part of the basic utilities in all households, economical basic data tariffs must be available.

³¹⁴ Primary energy total EU forecast for the year 2020 = 1634.271 Mtoe Source: European Commission Directorate-General for Energy and Transport: European Energy and Transport - Trends to 2030, Update 2007, Belgium 2008.

³¹⁵ Moreover, the use of an SDM system will enable a maximum integration of energy efficient distributed energy resources such as renewable energy and will participated to reaching the EU 20 % share of renewable energy target by 2020. These two achievements (reduced energy use, and higher integration of renewables) will also lead to reduction in CO₂ emissions and participate to reaching the third EU target of 20 % reduction in greenhouse gases. – However no robust quantification of the impacts of implementing a SDM system on the CO₂ emissions and increased share of renewable energy sources would be determined in the study.

³¹⁶ (0.251 toe primary energy = 10,500MJ primary energy = 1MWh electricity [EcoReport])

³¹⁷ See Task 1, the estimated projected electricity consumption in EU-27 for the year 2020 is 3978 TWh

- The unbundling of grid operators from global market actors is already a demand from the EC. More pressure to fulfil this demand appears to be necessary in many countries.
- Mandatory requirements in ICT standards of household devices are necessary to fulfil SDM-requirements.

2.4. CONCLUSIONS TASK 2

The implementation of ICT application in the buildings sector, the industrial sector and the energy sector could potentially provide energy savings through increased energy efficiency.

Findings showed that in an Eco-scenario:

- The buildings sector could reduce its residential buildings energy consumption of almost 35 % which is equivalent to savings 151.9 Mtoe. In the service sector, the energy consumption could be reduced of 17.2 % which is equivalent to 30 Mtoe.
- The industrial sector could reduce its energy use for electrical drivers (motors) of almost 10% leading to savings of 11.6 Mtoe
- The energy sector could reduce its primary energy consumption of 37.2 Mtoe. Such quantity of primary energy could in theory produce 148 TWh of electricity³¹⁸ which is equivalent to 12.8 Mtoe³¹⁹.

The important savings in the buildings sector need to be considered in perspective with the overall significance of the building's sector in Europe which represents over half the electricity consumption in Europe³²⁰.

Future work is needed in order to reach these improvement targets which require a large scale deployment of ICT based technologies for energy efficient buildings and energy efficient electricity networks. The effectiveness of the existing and already initiated policy options needs to be supported and needs a critical review in the mid-term. The evaluation should not only determine if the expected improvement potential (e.g. in the buildings sector) has been achieved but should provide an understanding of which measure (or combination of measures) achieved the improvement. In this respect, recommendations include: improvement and monitoring of statistical data, regulatory watch (initiating and monitoring self-regulation), information and guidelines and technology development in different areas identified in Task 2 (e.g. semiconductor, components, and printing circuit board industry).

³¹⁸ Calculated based on the EuP EcoReport factor: 1 MWh electricity = 10,500 MJ= 0.251 toe primary energy

³¹⁹ 1 toe = 11.63 MWh

³²⁰ EuroStat see section 1.2.1

- List of Abbreviations (subtask 2.3)

AGC	Automatic Generation Control
AMI	Advanced Metering Infrastructure (also: Smart Metering)
AMM	Advanced Metering Management
AMR	Automated Meter Reading
BAU	Business As Usual (Scenario)
BAT	Best Available Technology
CIP	Critical Infrastructure Protection
CRISP	Distributed Intelligence in Critical Infrastructures for Sustainable Power
CPP	Critical Peak Pricing (tariff)
DER	Distributed Energy Resources
DG	Distributed Generation
DLC	Direct Load Control
DLMS	Device Language Message Specification
DNO	Distribution Network Operator
DRR	Demand Response Resources
DSM	Demand Side Management
DSR	Demand Side Response
DG	Distributed Generation
DR	Demand Response
DRR	Demand Response Resources
D&RES	Distributed and Renewable Energy Systems
ED	Economic dispatch
EM	Energy Manager
EUP	End User Product
EUP	Energy Using Products
FEP	Front End processor
FACTS	Flexible AC Transmission Systems
ICCP	Inter-Control Centre Communications
ICT	Information and Communication Technology
ISO	Independent System Operator (comparable to TSO in USA context)
IED	Intelligent Electronic Device
IS	Information Systems
LAN	Local Area Network
LF	Load flow
MAS	Multi-agent System
MMI	Man Machine Interface
MUC	Multi-Utility Communication
NIU	Network Interface Unit
OPF	Optimal Power Flow
OSGi	Open Software Gateway initiative
PLC	Programmable Logic Controller

PMU	Phased measurement units
PV	Photo Voltaic#
RES	Renewable Energy Systems
RIU	Remote Internet Unit
RTP	Real-time Pricing (tariff)
RTU	Remote Terminal Unit
SA	Security Analysis
SCADA	Supervisory Control and Data Acquisition
SDM	Supply and Demand Management
TCP/IP	Transmission Control Protocol/Internet Protocol
TSO	Transmission System Operator
TOU	Time-of-use (tariff)
T&D	Transmission and distribution
UPS	Uninterruptible power supply
VPP	Virtual Power Plant
VSD	Variable speed drives
VVS	Voltage/ Var Scheduling
WAMS	Wide Area Monitoring System
WAN	Wide Area Network

- General Resources (subtask 2.3)

Website	Name / Publisher	Remarks
www.amimdm.com	AMI Meter Data Management Group	AMI
www.biofuelstp.eu	European Biofuels Technology Platform	
www.crisp.ecn.nl	Distributed intelligence in Critical Infrastructures for Sustainable Power	
http://dgfacts.labein.es/dgfacts	DGFACTS	Improvement of the quality of supply in Distributed Generation networks through the integrated application of power electronic techniques
www.dgnet.org	European Network for Integration of renewable Sources and Distributed Generation	
www.dgnet.org:8080/BUSMODd	Business Models in a World Characterised by Distributed Generation	
www.cepca.org	Consumer Electronics Powerline Communication Alliance	
www.demandresponseresources.com	IEA with SDM initiative	
www.dispower.org	Distributed Generation with High Penetration of Renewable Energy Sources	
www.dynamicdemand.co.uk	Research of British government in SDM	
www.enersearch.com/palas	PALAS, Power Line as an Alternative Local Access	
www.eu-deep.com	The European Distributed Energy Partnership	
www.eupvplatform.org	European Photovoltaic Technology Platform	
www.esttp.org	European Solar Thermal Technology Platform	
www.fenix-project.org	Flexible Electricity Networks to	

	Integrate the eXpected energy evolution	
www.fipa.org	Foundation for intelligent physical agents	
www.gridwise.pnl.gov	Pacific Northwest National Laboratory	DSM pilot projects in USA
www.gridpoint.com	The GridPoint Customer Portal	Energy consumer services
www.greenhomesconcierge.co.uk	A paid-for service which has already been successfully piloted across London and is designed for homeowners	Energy consumer services (allows utilities to reduce peak demand by enabling customers to conserve energy through a password protected online energy management portal)
www.hfpeurope.org	Hydrogen & Fuel Cells Technology Platform	
www.investire-network.com	Investigation on Storage Technologies for Intermittent Renewable Energies: Evaluation and recommended R&D strategy	
www.ipmvg.org	International Performance Measurement and Verification Protocol	
www.ired-cluster.org	ISSET institute University Kassel	
www.leonardo-energy.org	European platform on energy technology	
http://microgrids.power.ece.ntua.gr	MicroGrid	The interconnection of small, modular generation sources to low voltage distribution systems

www.m-u-c.org	Multi-utility communication	
www.naesco.org	National Association of Energy Service Companies in USA, (legislative and regulatory policies)	Energy consumer services
www.netz-euk.de	ISSET institute University Kassel	
www.powermatcher.net	Energy research center of the Netherlands	
www.iw.uni-karlsruhe.de	Forschungsgruppe Information & Market, Engineering University of Karlsruhe	
www.pnl.gov/gridwise	Gridwise Architecture council	USA
www.searcho.de	Service centric home	Home automation
www.selma.eu	Sicherer elektronischer Messdaten-Austausch (German project)	
www.smartgrids.eu	SmartGrids: European Technology Platform on Europe's Electricity Networks of the future (Vision and strategic research agenda)	
www.sustelnet.net	Policy and Regulatory Roadmaps for the Integration of Distributed Generation and the Development of Sustainable Electricity Networks	
www.synergy-project.org	Expanding the competitive intelligence in the European DER sector	
www..tempo.tm.fr	EDF tariff information	Dynamic tariffs

www.windplatform.eu	Technology Platform for Wind Energy	
www.zero-emissionplatform.eu	Technology Platform for Zero emission fossil fuel power plants	
www.zigbee.org	Zigbee Alliance	SDM with Wireless communication
www.z-wavealliance.org	Z-Wave Alliance	dito

- Further Publications (subtask 2.3)

EU / EC: Strategic research agenda for Europe's electricity networks of the future, Feb 2007

EU / EC: European Technology Platform SmartGrids - Vision and Strategy for Europe's Electricity Networks of the Future, Mar 2006

EC / DISPOWER: Distributed Generation with high penetration of renewable energy sources - Final public report, July 2006

EU / EC: Towards Smart Power Networks – Lessons learned from European research FP5 projects (General Information), Dec 2005

EUR21384: The Future Impact of ICT on Environmental Sustainability, 2004

EUR22580: Strategic Research Agenda for Europe's Electricity Networks of the Future, 2007

Rosenfeld, Herter, Jaske: Demand Response hardware and Tariffs - California's Vision and Reality (ACEEE Summer Study), Aug 2004

Kück: Smart grids – IEC 61850-7-420 - Vendors requirements (Siemens Presentation), June 2007

SEI: Demand Side Management in Ireland - Evaluating the Energy efficiency opportunities, Jan 2008

Centre for Energy Policy and Economics - Swiss Federal Institutes of Technology: Der Einfluss moderner Gerätegenerationen der Informations- und Kommunikationstechnik auf den Energieverbrauch in Deutschland bis zum Jahr 2010 – Möglichkeiten zur Erhöhung der Energieeffizienz und zur Energieeinsparung in diesen Bereichen, Jan 2003

Various: Realizing the Potential of Energy Efficiency (UNO Foundation), July 2007

Various: Telecommunications-based Opportunities to Reduce Greenhouse Gas Emissions (Climate Risk Pty Limited - Australia), 2007

TNS Infratest Wirtschaftsforschung Munic: Horizons 2020 - A thought-provoking look at the Future (Siemens), Oct 2004

Commission for Energy Regulation: Demand Side Management & Smart Metering (Ireland), Mar 2007

Bennich, Persson: Methodology and first results from end-use metering in 400 Swedish households (The Swedish energy agency), June 2006

Porter: Smart Metering – real energy benefits (BEAMA), June 2006

Kester, Zondag, Kamphuis, Bakker: Sustainability of Dutch Home Automation Projects, Evaluation and Recommendations (ECN), June 2006

Siderius, Dijkstra: Smart Metering for Households: Cost and Benefits for the Netherlands (SenterNovem), June 2006

Laurent: Specific electricity consumptions and energy saving potential in French dwellings (EDF France), June 2006

Sernhed: What's on the top? Household load patterns and peak load problems (Lund University, Department of Energy Sciences), June 2006

Various: Analyses of Demand Response in Denmark (Risø National Laboratory Ea Energy Analyses RAM-løse edb - Denmark), Oct 2006

Various: Estimating Demand Response Load Impacts: Evaluation of Baseline Load Models for Non-Residential Buildings in California (ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY), Jan 2008

Various: High Tech: Low Carbon The role of The European digiTal TecHnology indusTry in Tackling climaTe cHange (EICTA), April 2008

DEFRA: UK Energy Efficiency Action Plan, 2007

IDAE: Saving and Energy Efficiency Strategy in Spain, July 2007

Ministry of Economic Development: Italian Energy Efficiency Action Plan 2007, July 2007

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3. Discussion and Quantification of ICT Applications Enabling Energy Efficiency through Dematerialisation – 2020 Outlook

3.0. INTRODUCTION

As stated in the Task 1 document, Information and Communication Technologies (ICT) can affect the environment directly or indirectly and such effects can be of following three types:

- First order effects include the direct environmental impacts caused by an ICT equipment during its whole life cycle
- Second order effects relate to the application of ICT in other sectors, thus causing an indirect impact on the environment e.g. the environmental impact of a production process can be different when an ICT technology is applied to manage or monitor the process.
- Third order effects are macro-level indirect effects resulting from structural and behavioural changes and adaptation to the ICT services as a part of everyday life and business (e.g. e-work practices).

This section focuses on the **second and third level effects** related to the application of ICT based solutions for the dematerialisation of goods and services. The section will assess the different ICT-based applications which can provide energy and resource savings through dematerialisation. Quantification of the savings will be provided where possible.

Dematerialisation can be defined as “the reduction of the total material and energy throughput of any product or service, and thus the limitation of its environmental impact. This includes reduction of raw materials at the production stage, of energy and material inputs at the use stage, and of wastes at the disposal stage”³²¹. In other words, dematerialisation is the reduction of material and resource use in general, for achieving an equivalent or increased quantity and quality of production of goods and/or services, including ones at the level of the products, at the level of sectors of the economy, or in the economy as a whole. Dematerialisation can be absolute, meaning that less materials and energy are used, or relative, meaning that less materials and energy are used per unit of economic value produced (e.g. GDP). Relative dematerialisation refers to the phenomenon of de-linking economic growth and natural resource use, i.e., meaning that progressively, less materials and energy are

³²¹ UNEP definition: John Manoochchri: *Consumption Opportunities Strategies for change – A report for decision-makers*, UNEP, Geneva, 2001, online available at: http://www.unep.ch/scoe/documents/en_SCO.pdf

used per unit of economic value produced. Thus, economic growth is separated from the natural resource base.

This definition resonates with the notion of eco-efficiency defined as “the delivery of competitively priced goods and services that satisfy the human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity [...]”³²² or more simply as “doing more with less”. This can be achieved through the use of ICT based services and technologies replacing kilogram of materials by bites.

Dematerialisation through the use of ICT can translate into:

- the replacement of material goods by non-material substitutes - “Bits instead of atoms” (for instance a letter on paper replaced by an electronic mail)
- the reduction in the use of material systems or of systems requiring large infrastructures (for instance using telecommunications instead of using a car to go to work)
- the conception and manufacture of products using less materials and energy and conception of a smaller or lighter product (see sub-task 3.2)

This phenomenon is used in various business and service sectors. The two first areas will mainly be covered in sub-task 3.1 and the third area by sub-task 3.2.

The objectives are to discuss and evaluate the future energy efficiency improvements achievable through dematerialisation supported by ICT applications, and identify if further policy action / research is needed.

Finally, dematerialisation cannot be applied to all products. However, even in sectors where dematerialisation cannot occur (e.g. food products cannot be digitalised) ICT technologies still have an impact by allowing the development of new services. Also, dematerialisation as understood in “virtual worlds” such as “Second Life” is also supported by ICT applications and represents a dematerialised world.

This can translate into the shift towards a more service oriented economy, leading to a “re-structuration” of society. However, this is out of the scope here as there are no direct links with energy efficiency and no quantification/recommendation will be made on these aspects.

In order to analyse and estimate the potential that ICT-based application can provide to improve the energy efficiency in these areas, each subtask proposes to develop:

- Baseline scenarios (reference scenarios): mainly based on literature data, these scenarios do not take into account the increase in the use of ICT-based application. These scenarios are the reference against which to evaluate the alternative scenarios.

³²² World Business Council for Sustainable Development definition (WBCSD) <http://www.wbcsd.org>

- Business-as-Usual scenarios (BAU): which assume continuity is maintained considering the current situation and trends
- Eco-scenarios: which assume that there is a push for ICT-based energy efficient solutions.

In addition, where no solid quantified data could be obtained, “low”, “medium” and “high” hypotheses were used in order to provide a reasonable range of data and order of magnitude.

3.1. DEMATERIALISATION OF SOCIETY

This section will focus on five specific areas of dematerialisation:

- E-government (focus on e-health and e-taxation)
- Audio/video conferencing
- E-work
- Dematerialisation of materials and services
- E-commerce

The approach followed to analyse each of these areas of dematerialisation follows 4 steps:

- Description of e-service and related ICT applications providing energy efficiency gains in the area considered
- Analysis of the policy framework at EU 27 level, business initiatives, analysis of the e-service status and trends in the EU (BAU situation and scenario)
- Analysis of case studies (based on literature) and assessment of the improvement potential at a micro level
- Recommendations and evaluation of the option (Eco versus BAU scenario)

3.1.1. E-GOVERNMENT

3.1.1.1 Description of e-government and related ICT applications

E-government is the use of Information & Communication Technologies (ICTs) to make public administrations more efficient and effective. E-government refers to government’s use of information and communication technologies to exchange information and services with citizens, businesses, and other arms of government. E-government may be applied by the legislature, judiciary, or administration, in order to improve internal efficiency, the delivery of public services, or processes of democratic governance. The most important anticipated benefits of e-government include improved efficiency, convenience, and better accessibility of public services.

While e-government is often thought of as "online government" or "Internet-based government" (e.g. e-voting, e-taxation), many non-Internet "electronic government" technologies can be used in this context. Some non-Internet forms include telephone, fax, PDA³²³, SMS³²⁴ text messaging, MMS³²⁵, wireless networks and services, Bluetooth, CCTV³²⁶, tracking systems, RFID³²⁷, biometric identification, road traffic management and regulatory enforcement, identity cards, smart cards, and other NFC³²⁸ applications; polling station technology (where non-online e-voting is being considered), TV and radio-based delivery of government services, e-mail, online community facilities, newsgroups and electronic mailing lists, online chat, and instant messaging technologies.

In this section, the focus will be less on the ICT applications allowing more efficient services in terms of rapidity and quality, but more on the ICT based applications allowing energy savings with the same (or enhanced) quality of service. Therefore not all applications mentioned above will be analysed, such as CCTV³²⁹. Also RFID systems will be developed in Sub-Task 3.2, and traffic management being already a well documented issue, it was decided it would be discarded from the present study.

There are also some technology-specific sub-categories of e-government, such as m-government (mobile government), u-government (ubiquitous government), and g-government (GIS/GPS applications for e-government). Other aspects relating to e-governance and to the use of ICT for a participative democracy in policy making, for transparency of policy processes will not be explored here, as they do not represent a potential for improving the energy efficiency of public services, but have been the subject of numerous studies³³⁰.

³²³ Personal Digital Assistant

³²⁴ Short Message Service

³²⁵ Multimedia Messaging Service

³²⁶ Closed-circuit television (CCTV) is the use of video camera to transmit a signal to a specific, limited set of monitors (e.g. surveillance cameras)

³²⁷ Radio Frequency Identification

³²⁸ Near Field Communication or NFC, is a short-range wireless communication technology which enables the exchange of data between devices over a short distance (hands width). Examples of current applications include: mobile ticketing in public transport, mobile payment (mobile phone acts as a debit/credit payment card), etc.

³²⁹ CCTV and surveillance cameras could be considered as energy saving technologies as they might enable to reduce the workforce of a surveillance team (i.e. number of guards for a facility) and therefore reduce e.g. the commute associated (transport), the energy consumption of the surveillance team (e.g. reduced need for office space). However such savings are not easily quantifiable and it was decided to focus on ICT based applications allowing more "direct" savings.

³³⁰ Christine Leitner, e-Government in Europe: The State of Affairs. (2003) for the European Commission. http://www.eipa.eu/files/repository/product/20070214113429_egoveu.pdf

E-government applications include practices which substitute for a traditional service (e.g. e-vote, e-tax) and ICT-applications enabling new products with new functionalities. An example of a new product is the electronic identification card which can store a significant amount of sophisticated data into a small volume. The evaluation of the energy savings enabled by such “new product” is difficult as there is no point of comparison and the functionalities compared to the traditional product (e.g. a traditional identification document) are not comparable.

E-taxation has been expanding in European countries (e.g. Sweden, Belgium, France, Portugal, Ireland, Hungary³³¹, Slovenia, etc.).

3.1.1.2 Analysis of the policy framework at EU level, business initiatives, analysis of the e-service status and trends in the EU

■ Status

All member states provide services online, and most have e-government strategies. E-government appears to be a political priority across Europe and this is reflected within the i2010 Benchmarking studies and policy framework (see next section). In the i2010, the policy indicator for e-government is defined as the “number of basic public services fully available online” (see Table 114). E-government includes the health services as well (detailed description of e-health services in Annexe 1).

The i2010 action plan defines a second indicator describing the level of sophistication of the online services (see Figure 52).

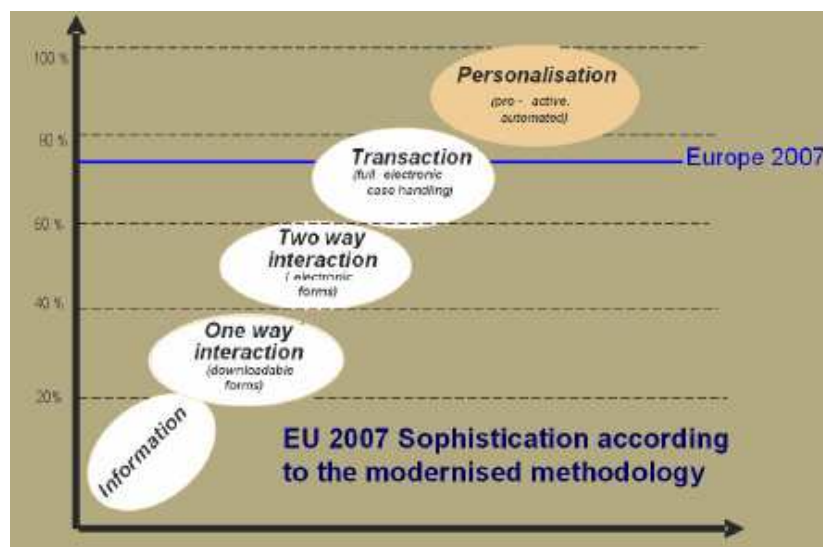
Table 114: Public services covered by the i2010 Action Plan³³²

Citizens	Businesses
Income Taxes	Social Contribution for Employees
Job Search	Corporate Tax
Social Security Benefits ²	VAT
Personal Documents ³	Registration of a New Company
Car Registration	Submission of Data to the Statistical Office
Application for Building Permission	Custom Declaration
Declaration to the Police	Environment-related Permits
Public Libraries	Public Procurement
Birth and Marriage Certificates	
Enrolment in Higher Education	
Announcement of Moving	
Health-related Services	

³³¹ <http://ec.europa.eu/idabc/en/document/5965/5584>

³³² Cap Gemini. *Online Availability of Public Services: How is Europe Progressing?* 2005. Prepared for the European Commission Directorate General for Information Society and Media.
http://ec.europa.eu/information_society/eeurope/2005/doc/all_about/online_5th_measurement_fv4.pdf

Figure 52: EU achievement on five stage sophistication model for online services



■ Policy framework and business initiatives

The European main policy initiative is the eGovernment Action Plan which focuses efforts on five priorities:

- Inclusive e-government (flexible and multi channel services)
- Efficiency and effectiveness (measurement)
- High impact services (eProcurement)
- Key enablers (eID)
- eParticipation (preparatory action)

This action plan is supported by 6 European programs:

- Information society Technologies (FP6 - funded eGovernment research under the Information society Technologies activity area)
- ICT PSP (The Information and Communication Technologies Policy Support Programme is a major component of the EU's Competitiveness and Innovation Programme (CIP). One of the overarching aims of ICT PSP is to stimulate innovation and competitiveness through the wider uptake and best use of ICT by citizens, governments and businesses.)
- eTen (eTEN programme has funded projects supporting the deployment of innovative, trans-European ICT services in the public interest)
- IDABC (Interoperable Delivery of European eGovernment Services to public Administrations, Business and Citizens. It takes advantage of the opportunities offered by information and communication technologies:

-to encourage and support the delivery of cross-border public sector services to citizens and enterprises in Europe,

-to improve efficiency and collaboration between European public administrations and,

-to contribute to making Europe an attractive place to live, work and invest.)

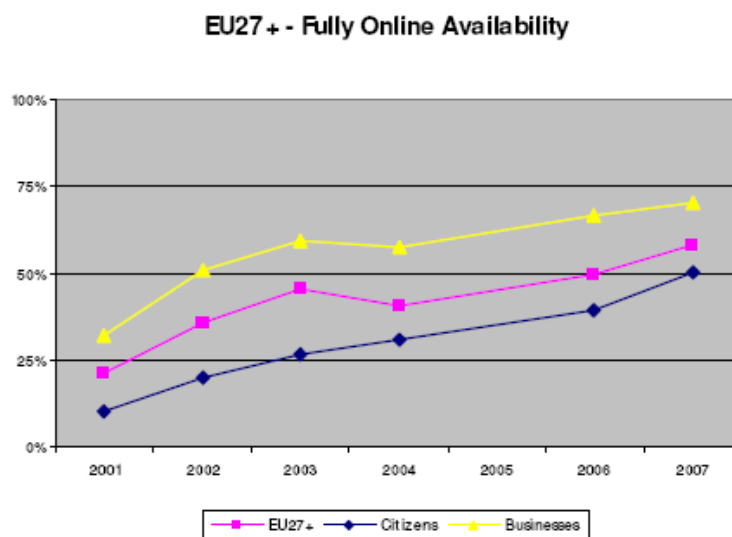
- Epractice.eu (portal which seeks to facilitate the exchange of good practice and disseminate experiences to eGovernment, eInclusion and eHealth practitioners)
- eParticipation (supports pilot projects in real-life environments that demonstrate the use of Information and Communication Technologies to bolster citizens' participation in democratic decision-making)

On the business side, it is worth mentioning that ICT leaders have been proposing technologies, and infrastructure to enable the deployment and realisation of e-government practices: e.g. developing mechanisms of electronic signatures and certification.

■ Trends

According to the 2007 Benchmarking report of the supply of online public service³³³, the supply of fully online availability services has increased in Europe, with more than half (58 %) of all services qualifying as such in 2007 (increasing from 50 % in 2006) (see Figure 53).

Figure 53: Progression of full online availability



Demand for online services has also grown as the supply of online services has been made available. Eurostat surveys show that the proportion of the population and businesses obtaining information from public websites has increased as well as the demand for more sophisticated operation (filling and downloading forms). The

³³³ Cap Gemini. *The User Challenge, Benchmarking the supply of online public services*. 2007. Prepared for the European Commission Directorate General for Information Society and Media
http://ec.europa.eu/information_society/eeurope/i2010/docs/benchmarking/egov_benchmark_2007.pdf

Eurostat data also shows that the enterprises are more intensive users of government services; however, there is still room for expanding e-government practices.

Table 115: Information society - E-government indicators³³⁴

	2004	2006	
	EU 25	EU 25	EU 27
Percentage of individuals using the Internet for interacting with public authorities: obtaining information	21%	22.6%	21.3%
Percentage of individuals using the Internet for interacting with public authorities: downloading forms	10%	14.1%	13.3%
Percentage of individuals using the Internet for interacting with public authorities: returning filled forms	6%	9.3%	8.8%
Percentage of enterprises using the Internet for interacting with public authorities: obtaining information	45%	55.0%	55.0%
Percentage of enterprises using the Internet for interacting with public authorities: downloading forms	41%	56.0%	55.0%
Percentage of enterprises using the Internet for interacting with public authorities: returning filled forms	29%	45.0%	44.0%

Difficulties while accessing public websites are one of the main inhibitors to greater use of e-government services³³⁵. Major benefits include saving of time, transportation needs, paper-based documents, and storage space.

3.1.1.3 Analysis of case studies and assessment of the improvement potential at a micro level

Most e-government applications are intended to improve the quality of the public services and enhance the accessibility to information and increase citizens' participations to various decision processes (.g. mobile government, e-passports, e-democracy).

Among all practices covered by e-government, e-archives could potentially reduce CO₂ emissions of library services and other data storage centres³³⁶. Also, replacing paper ballots by e-voting could potentially reduce paper consumption. However, these practices might present less potential for development at a large scale than e-taxation (either because they do not enable significant energy savings such as e-passports, or either because they do not present a big potential for take up at the EU level), and for this reason, and also because of unavailability of existing studies related to other

³³⁴ EUROSTAT

http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/I/15&language=en&product=Yearlies_new_science_technology&root=Yearlies_new_science_technology&scrollto=0

³³⁵ PLS Ramboll Management A/S *Top of the web – Survey on quality and usage of public services*, November 2003. http://ec.europa.eu/information_society/eeurope/2005/doc/all_about/quality_usage_final_report_2003.pdf

³³⁶ In the *Guideline for Information and Communication Technology (ICT) Eco-Efficiency Evaluation* published in March 2007 by the Japanese Eco-efficiency forum, a case study on a library shows that adopting a library management system based on barcodes could save 3,400 kg CO₂ per year (10,000 books library), mostly due to working force reduction and paper consumption reduction, even though generating an extra 556 kWh/ year electricity consumption for PC, server, and other ICT devices operation. http://www.jemai.or.jp/JEMAI_DYNAMIC/data/current/detailobj-2687-attachment.pdf

applications, it was decided to focus on this specific application : **e-tax and e-health** and to directly adopt a EU-wide scale analysis (see BAU and Eco-scenarios in next section 3.1.4.3); however, still providing insights on the specific situation of some MS where available.

Existing studies measure the efficiency and effectiveness of e-government more in terms of quality of service, availability of the service, and time savings rather than in terms of environmental benefits³³⁷.

3.1.1.4 Recommendations and evaluation of the option

- BAU and Eco-scenario impact analysis at EU level

As no case study was available to assess the impacts of e-government as a whole in terms of energy savings, it was decided to focus on specific applications within e-government:

- **e-taxation: the online declaration of taxes for citizens and businesses**
- **e-health: the use of a smart card for medical care reimbursement**

[E-health encompasses a large range of services which mainly aim at improving the quality of the healthcare in terms of accessibility, rapidity and effectiveness (e.g. remote monitoring). Energy efficiency is not the primary goal and most e-health related applications are poorly documented with regards to their potential to improve the energy efficiency of a health service. In the field of telemedicine, the “store and forward” application³³⁸ could reduce printed material and transportation needs, and postal services. However, no case study was available to quantify these savings. Remote consultations can reduce patients’ and doctors’ amount of travel to undertake. However, this specific application only applies to low density areas and remote areas and are not relevant in urban zones. Online information could also potentially reduce the need for information leaflets and lead to reduce paper consumption just like e-prescription. However, it seems that the most significant application appears to be the use of smart cards (insurance cards, medical record cards) which enable the avoidance of invoices when consulting a doctor or buying medicine and is potentially applicable at a large scale in Europe. In France for example, about 55 million people possess a health smart card (“carte vitale”) and every month about 77 million of electronic invoices are issued, representing over 60%

³³⁷ - PLS Ramboll Management A/S *Top of the web – Survey on quality and usage of public services*, November 2003. http://ec.europa.eu/information_society/eeurope/2005/doc/all_about/quality_usage_final_report_2003.pdf
 - eGovernment Economics Project eGEP http://82.187.13.175/eGEP/asp/E_Home.asp
 - Capgemini. *The User Challenge Benchmarking The Supply Of Online Public Services 7th Measurement*. September 2007
http://ec.europa.eu/information_society/eeurope/i2010/docs/benchmarking/egov_benchmark_2007.pdf

³³⁸ See explanation in Annexe 1

of all invoices³³⁹. Therefore it was decided to focus on the use of smart cards for medical care reimbursement.]

In order to complement the available literature on e-tax and e-health, questionnaires were sent to MS ICT departments in charge of e-government deployment in order to collect data on e-taxation and e-health practices and to their related savings. Data related to the status and trends specific to these practices was collected in order to build future improvement scenarios.

- Status and trends

E-taxation for citizens and businesses

In 2003, based on the results of a survey related to e-government practices³⁴⁰ (Table 116) and as far as income tax declarations by citizens are concerned, and based on the replies to our questionnaire (3 replies from Belgium, Luxembourg and Slovenia³⁴¹) to MS for the year 2005, it can be assumed that for the year 2005 in Europe an average of between **5 and 10 %** of citizen declared their income tax online. For the year 2020 replies to the questionnaires show that MS estimate the take up of such practice to an average of between 80 and 90%. This target is also mentioned as a long term target in the European survey.

Table 116: Online declaration by citizens – income tax (2003)³⁴⁰

Country	Income tax		
	Transactions		
	Total	On-line	On-line %
Norway	3,149,000	1,102,150	35%
Denmark	1,306,000	404,860	31%
Spain	16,192,040	2,326,796	14%
Sweden	6,800,000	748,000	11%
Germany	30,000,000	1,200,000	4%
Belgium	5,657,163	57,703	1%
Total	57,447,040	5,781,806	

In 2003, based on the results of the same survey (Table 117) and as far as VAT declaration is concerned, and based on the replies to our questionnaire to MS for the year 2005, it can be assumed that for the year 2005 in Europe an average of between **15 and 20 %** of businesses declared their VAT tax online. Same share is assumed for other business tax declaration such as income declaration. For the year 2020 replies to the questionnaires show that MS estimate the take up of such practice to 100%.

³³⁹ 2007 from Ministry of Health, Youth and Sports http://www.items.fr/IMG/pdf/GF_2007_Michele_Thonnet.pdf

³⁴⁰ Ramboll Management. *Top of the web. User Satisfaction and Usage*. 2004 Prepared for DG INFSO e-government unit

³⁴¹ Each of the responding MS asked for their replies to remain confidential

Table 117: Online declarations by businesses – VAT (2003) ³⁴⁰

Country	VAT		
	Transactions		
	Total	On-line	On-line %
Denmark	1,010,000	454,500	45%
Norway	1,184,000	236,800	20%
Finland	3,000,000	480,000	16%
Belgium	2,982,055	157,751	5%
Sweden	440,000	13,200	3%
Total	8,616,055	1,342,251	

E-heath: the use of a smart card for medical care reimbursement.

The replies to our questionnaire did not provide sufficient data to assess the current use of smart-card based e-health systems in Europe, and the take up of such practice in the countries where it is implemented (e.g. France, Slovenia, Austria, Estonia (electronic ID), Finland, and Hungary). We therefore make the assumption that the current take up of online reimbursement of medical claims is similar to the take up of online tax payment practices (5%-10% for the year 2005). Specific data for France showed that in 2007, already 60 % of all invoices³⁴² were issued electronically for the 55 million smart card users (“carte vitale”).

Moreover, the eHealth ERA website, which serves as an online platform to foster coordination of Member States’ eHealth strategy formulation and implementation, shows that the implementation of a smart card is planned in the e-health strategy of most MS (e.g. the Czech Republic, Finland, Greece, projected in Germany, Bulgaria, Latvia, and Italy) and is a priority development field in most MS as well.

Based on these trends, we can assume that in 2020, a realistic ECO scenario is that about 60 % of all invoices could be electronic (all MS reach the French situation) and that the BAU scenario could be that all MS reach half the target: 30 % of all invoices related to medical care are electronic in 2020.

- BAU and Eco-scenario

Assumptions for the scenarios

Based on the replies to these questionnaires, it was decided to **focus on energy savings related to avoided paper** when estimating the environmental benefits of e-tax and of the use of a health smart card compared to a scenario where less electronic transactions are enabled. The extra electricity consumption due to using computers and the positive effects of avoided transport are assumed to be negligible as compared to paper savings³⁴³. In the scenarios (BAU and Eco), we assume the users do not print.

³⁴² 2007 from Ministry of Health, Youth and Sports http://www.items.fr/IMG/pdf/GF_2007_Michele_Thonnet.pdf

³⁴³ Previous LCA analysis comparing sent paper based documents and online documents show that the paper production phase is the most impacting phase and that the effects of avoided transport and of

Box 1: Comparison of paper production and end-of-life vs. computer use

In order to illustrate why it was chosen to assume the extra electricity consumption due to computer usage is negligible against paper production and end-of-life the following calculations can be made:

According to Table 123 (see calculation related to Table 8), the impacts of the production and end-of-life of 150 g of paper can be calculated (150 g of paper is the estimated average weight of a tax declaration see further explanations in Table 121). Results are shown in Table 118:

Table 118: Estimated impacts of paper production and end-of-life

Paper	Total Equivalent electricity savings [production and end-of-life]	Total savings [production and end-of-life] CO ₂ eq.
1 ton	2.89 MWh	1.6934 tons
1g	2.89 Wh	1.69 g
150 g	433.5 Wh	253.5 g

On the other hand, the impacts related to the use of a computer during 20 min can be calculated based on the typical power consumption of desktop PC and LCD monitors (assuming such equipment is used).

Table 119: Impact of using a desktop computer for 20 min (use phase)

	Power requirement ³⁴⁴ Unit	Type	Electricity use (20 min)	Equivalent CO ₂ emissions ³⁴⁵
PC:	78 W	Desktop PC	36.5 Wh	16.7 g
screen	31.4 W	17" LCD display		

This calculation shows that producing 150 g of paper has a more significant impact (in term of energy and CO₂ emissions) than using a computer for 20 min. The user would have to stay about 4 hours on his computer in order to have a similar impact to that of 150 g of paper.

Overall synergetic effects of e-government practices, such as the reduction of office space needed by administrations due to increase of online practices, and less need to process data (i.e. less workforce needed) were not assessed for two reasons:

extra electricity use due to ICT equipment are negligible (Online billing at Deutsche Telekom – analysis out by Öko Institute for Deutsche. Telekom in ETNO. Greenhouse Gas effects of Information and Communication Technologies, Project studies, 2005 and Moberg et al. *Screening environmental life cycle assessment of printed, web based and tablet e-paper newspaper*. 2007. KTH Centre for sustainable Communications, Stocholm, Sweden)

³⁴⁴ Typical power consumption values were taken from the EuP preparatory Lot 3 study on computers and monitors and refer to a 2005 situation. It could be expect that a reduction of these figures will occur in 2020 compared to 2005, and therefore these values are an overestimation.

³⁴⁵ EuP EcoReport Emission factor: 1 kWh = 0.4582 kg fixed throughout 2005-2020, which implies a overestimation of the CO₂ emissions.

- Replies to the questionnaires shows that even in MS with 30 % of online tax payers, no office space reduction was observed. This can be explained by the fact that such reductions in office space would only occur if e-practices become significantly widespread and do not serve as complementary channels but as effective substitutes
- No statistic data is available to assess the energy use of administration buildings and to evaluate the share of space or workforce dedicated to tax processing

In order to evaluate the savings related to avoided paper through the use of e-tax and e-health application, a Baseline scenario, a BAU-scenario and an Eco-scenario were constructed based on the identified trends and status.

- **Baseline scenarios** were constructed, assuming the take up of e-government practices stays as in 2005 (this allows to have a reference scenario). These baseline scenarios serve as a reference point for the year 2020, for calculating the future energy savings enabled by further take-up of e-government practices. The assumptions on the share of online tax declaration and electronic reimbursement claim of medical care are presented in Table 120.
- In the **BAU-scenarios** for e-tax, we assume the paper declarations are sent to all tax payers. In the field of online tax declaration some MS countries send the paper declaration to all tax-payers (e-payers and traditional) which leads to no reduction in paper consumption (however, such practice still provides reduction of the use of postal services, time for processing the data, etc.).
- In the **Eco-scenarios** we assume that the paper declarations are only sent to traditional tax payers (paper-based) and that **online tax payers download their tax-form on a website.**

Table 120: Assumptions for future trends in e-government services

	Low 2005	High 2005	Low 2020	High 2020
Baseline Scenario				
Online Tax declaration (citizens)	5%	10%	5%	10%
Baseline scenario				
Online tax declaration (business)	15%	20%	15%	20%
Baseline scenario				
Online reimbursement claims	5%	10%	5%	10%
BAU-scenario / e-tax				
Share of online tax declaration (citizens) Tax declarations are sent to all tax-payers	5%	10%	80%	90%
BAU-scenario / e-tax				
Share of online tax declaration (business) Tax declarations are sent to all tax-payers	15%	20%	100%	100%
BAU-scenario / e-health				
Share of online reimbursement claims	5%	10%	30%	30%
Eco-scenario / e-tax				
Share of online tax declaration (citizens) e-payers download the tax form	5%	10%	80% No paper declaration is sent	90% No paper declaration is sent
Eco-scenario / e-tax				
Share of online tax declaration (business) e-payers download the tax form	15%	20%	100% No paper declaration is sent	100% No paper declaration is sent
Eco-scenario / e-health				
Share of online reimbursement claims	5%	10%	60%	60%

Further assumptions on the amount of paper contained in a tax declaration, reimbursement claim etc., and on the number of subscribers were made based on the French situation and on the replies to the questionnaire (Luxembourg, Belgium and Slovenia) (Table 121). The **basic data related to the total number of employees in EU 27** is based on data from Eurostat³⁴⁶ and from the EU Directorate General for Employment³⁴⁷. In both scenarios, it was assumed that the number of tax-payers is equal to the number of employees, however, it should be noted that other professionals pay taxes and therefore the uptake of e-taxation could be higher.

³⁴⁶ Eurostat – Statistics in focus 2006, Long term population projections at national level

http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NK-06-003/EN/KS-NK-06-003-EN.PDF

³⁴⁷ Employment in Europe 2007 report available at

http://ec.europa.eu/employment_social/employment_analysis/employ_en.htm

Table 121: Assumptions and statistics used

	Income tax declaration (citizens)	VAT and income tax declaration (business)	Reimbursement claim for medical care
Average number of pages (A4)	30	15	2-3
Weight (g)	150	75	7.5
Issues per year	1	2	3
Total number of users 2005 (traditional + online services)	215,920,000 =number of employees	13,948,742 ³⁴⁸ =number of enterprises	483,568,400 =Total population
Total number of user 2020 (traditional + online services)	231,984,400 ³⁴⁹ =number of employees	13,948,742 =number of enterprises	496,400,000 =Total population

Table 122: Paper consumption in tonnes for the different scenarios

	%Online transactions		Paper consumption (t)	
	Low 2020	High 2020	Low 2020	High 2020
Baseline Scenario / e-tax Online Tax declaration (citizens)	5%	10%	34,798	34,798
Baseline scenario / e-tax Online tax declaration (business)	15%	20%	2,092	2,093
Baseline scenario / e-health Online reimbursement claims	5%	10%	10,610	10,052
BAU-scenario / e-tax Share of online tax declaration (citizens) Tax declarations are sent to all tax-payers	80%	90%	34,798	34,798
BAU-scenario / e-tax Share of online tax declaration (business) Tax declarations are sent to all tax-payers	100%	100%	2,092	2,092
BAU-scenario / e-health Share of online reimbursement claims	30%	30%	7,818	7,818
Eco-scenario / e-tax Share of online tax declaration (citizens) e-payers download the tax form	80%	90%	6,960	3,480
Eco-scenario / e-tax Share of online tax declaration (business) e-payers download the tax form	100%	100%	0	0
Eco-scenario / e-health Share of online reimbursement claims	60%	60%	4,468	4,468

Resulting savings in different scenarios

Based on the assumptions presented in Table 121, results in terms of equivalent paper consumption related to the different tax forms and reimbursement claims were calculated in the different scenarios. These paper savings were then translated into

³⁴⁸ Business demography indicators from Eurostat, Number of enterprises active for the year 2005 (data was only available for 16 MS: Bulgaria, Czech Republic, Spain, Estonia, Italy, Cyprus, Latvia, Luxembourg, Hungary, Netherlands, Portugal, Romania, Slovakia, Finland, Sweden and the UK.

³⁴⁹ See calculations from Table 144: Basic data on employment and trends until 2030

electricity savings, based on the necessary quantity of electricity to produce one tonne of paper and on the end-of-life treatment of paper in Europe:

- The impacts of avoided paper are evaluated in terms of avoided paper production which impacts are measured in terms of primary energy used during the production process. A factor of **31 MJ/kg** and **1.65 kg CO₂ eq./kg** paper produced was taken as reference, based on the Life Cycle Inventories database Ecoinvent 1.3 inventory for the European situation³⁵⁰.
- End-of-life is also interesting to consider. At the scale of Europe a wide range of end-of-life scenarios are possible. The end-of-life scenario assumed for Europe is the following: based on European statistics on waste paper recovery for 2005 (CEPI, 2006):
 - 60% recycling (Recycling of newspaper was modelled as closed-loop)
 - 30% landfill (Landfill was modelled without energy recovery)
 - 10% incineration (Incineration was modelled with energy recovery)

Based on European emissions factors for each waste stream in terms of CO₂ emissions and energy recovery³⁵¹ the following factors were assumed for the end-of-life of paper in Europe: **0.043 t CO₂ eq. /t** paper waste and **-58 kWh/t** paper waste (negative value as incineration generates electricity, and 1 MWh electricity = 10,500 MJ primary energy according to EcoReport³⁵²)

- Once the savings in primary energy were calculated they were converted into equivalent electricity in order to provide comparable data with other calculated savings. The assumption used is that 10,500 MJ of primary energy is equal to 1 MWh electricity energy according to EcoReport³⁵³.

These data allow to calculate the impacts related to the production and end-of-life of one ton of paper:

³⁵⁰ Ecoinvent 1.3, Paper, recycling, with deinking, at plant RER S

³⁵¹ Waste management options and climate change
http://ec.europa.eu/environment/waste/studies/climate_change.htm

³⁵² Official Life Cycle Analysis tool developed and used in the framework of the EuP Directive

³⁵³ Official Life Cycle Analysis tool developed and used in the framework of the EuP Directive

Table 123: Impacts of one ton of paper (production and end-of-life)

Ton paper	Production phase			End-of-life phase		Total	
	Savings in primary energy consumption (avoided paper production) MJ	Equivalent electricity savings based on the primary energy savings (avoided paper production)(MWh)	Savings in CO ₂ emissions (avoided paper production) t	Savings in electricity due to avoided end-of-life (MWh) electricity	Savings in t CO ₂ eq. due to avoided paper end-of-life phase (European scenario)	Total Equivalent electricity savings (MWh)	Total savingsTons CO ₂ eq.
1	31,000	= 31,000/10,500 = 2.95 MWh	1.65	-0.058	0.04	2.89	1.69

Data from Table 122 and Table 123 allows calculating the savings which are presented in Table 124 and Table 125.

Table 124: Paper savings in different BAU and Eco scenarios (2020)

Paper savings in tonnes / and in savings compared to baseline paper consumption	Low baseline vs. Low scenario 2020		Low baseline vs. High scenario 2020		High baseline vs. Low scenario 2020		High baseline vs. High scenario 2020	
	tonnes	%	tonnes	%	tonnes	%	tonnes	%
BAU-scenario / e-tax Share of online tax declaration (citizens) Tax declarations are sent to all tax-payers	0.0	0%	0.0	0%	0.0	0%	0.0	0%
BAU-scenario / e-tax Share of online tax declaration (business) Tax declarations are sent to all tax-payers	0.0	0%	0.0	0%	0.0	0%	0.0	0%
BAU-scenario / e-health Share of online reimbursement claims	2,792	26.3%	2,792	26.3%	2,234	22.2%	2,234	22.2%
Eco-scenario / e-tax Share of online tax declaration (citizens) e-payers download the tax form	27,838	80%	31,318	80%	27,838	90%	31,318	90%
Eco-scenario / e-tax Share of online tax declaration (business) e-payers download the tax form	2,092	100%	2,092	100%	2,092	100%	2,092	100%
Eco-scenario / e-health Share of online reimbursement claims	6,143	57.9%	6,143	57.9%	5,585	55.6%	5,585	55.6%

Table 125: Electricity and CO₂ eq. savings enabled through avoided paper production (2020)

Paper savings eq. Electricity savings GWh and equivalent CO ₂ Emissions savings from avoided paper production	Low baseline vs. Low scenario 2020		Low baseline vs. High scenario 2020		High baseline vs. Low scenario 2020		High baseline vs. High scenario 2020	
	MWh	tCO ₂ eq.	MWh	tCO ₂ eq.	MWh	tCO ₂ eq.	MWh	tCO ₂ eq.
BAU-scenario Online tax declaration (citizens)	0	0	0	0	0	0	0	0
BAU-scenario Online tax declaration (business)	0	0	0	0	0	0	0	0
BAU-scenario Online reimbursement claims	8,082	4,728	8,082	4,728	6,466	3,783	6,466	3,783
Eco-scenario Online tax declaration (citizens)	80,580	47,141	90,652	53,034	80,580	47,141	90,652	53,034
Eco-scenario Online tax declaration (business)	6,056	3,543	6,056	3,543	6,056	3,543	6,056	3,543
Eco-scenario Online reimbursement claims	17,781	10,402	17,781	10,402	16,165	9,457	16,165	9,457

Conclusions

- E-tax

The analysis shows that online taxation can only provide material savings when the paper documents are not sent to all tax payers but only to those declaring their taxes via the traditional channel. Therefore, the BAU situations in 2020 for e-tax show no savings at all compared to the baseline situation in 2020. Considering Eco-scenarios (no paper-based tax forms are sent to e-payers), e-taxation for citizens allows saving between 27,838 and 31,317 tonnes of paper, which corresponds to respectively **80,580 MWh and 90,665 MWh**, respectively equivalent to **47,141 t CO₂ and 53,034 t CO₂ eq.** compared to the baseline situation of e-tax for citizens in 2020.

The Eco-scenarios for e-taxation for businesses show that if all businesses declare online (complete substitution) then 2092.3 tonnes of paper could be avoided corresponding to savings of **6,056 MWh** (from avoided paper production) and **3,543 t CO₂ eq.** compared to the baseline situation of e-tax for businesses in 2020.

- E-health

The results show that in a BAU scenario, having electronic reimbursement of medical care implemented across Europe could save up to **2,792.3 tonnes of paper (=8,082 MWh which is equivalent to 4,728 t CO₂ eq)** and that a Eco-scenario could save up to **6,143 tonnes of paper (= 17,781 MWh which is equivalent to 10,402 tCO₂ eq).** compared to the baseline situation of e-health for citizens in 2020.

Electricity savings through avoided paper production from implementation of e-tax and e-health can be summed and averaged (average BAU, average Eco scenario).

Overall results are presented in Table 126.

Table 126: Electricity savings through avoided paper production (e-tax, e-health) (2020)

	Electricity savings (MWh)	Electricity savings (toe)	CO ₂ eq. (t)
Average BAU- scenario e-tax + e-health	7,274	625	4,256
Average Eco- scenario e-tax + e-health	108,645	9,342	63,560

■ Recommendations

The poor data availability on the environmental impacts of e-government services reveals the **need to include environmental aspects in research projects aimed at measuring the effectiveness and efficiency of e-government**. For example,

Moreover, in a recent project funded by the EC³⁵⁴, seven categories of barriers have been identified:

- Leadership failures: Slow and patchy progress to eGovernment can result from a lack of adequate leadership during any stage in the initiation, implementation, promotion and ongoing support of developments.
- Financial inhibitors: Concerns about the costs of implementing and developing eGovernment, together with inappropriate cost/benefit analysis approaches, can constrain or block the flow of investment at the levels necessary to support future eGovernment innovation.
- Digital divides and choices: Inequalities in skills and access can limit and fragment take-up of eGovernment. Failure to address clearly the needs of potential eGovernment users can also hamper take-up of eGovernment as even those citizens and businesses with appropriate levels of access may choose not to use available eGovernment services.
- Poor coordination: Lack of coordination and harmonization can put a brake on establishing appropriate eGovernment networks and services that cross governance, administrative and geographic boundaries.
- Workplace and organizational inflexibility: The realization of eGovernment benefits can be constrained or blocked by inflexibilities in responding to the need to make necessary changes in public administration practices, processes and organisational structures to allow them to be better able to make appropriate effective use of electronic networking capabilities.
- Lack of trust: Heightened fears about inadequate security and privacy safeguards in electronic networks and a general distrust of government can undermine confidence in eGovernment.

³⁵⁴ Oxford Internet Institute, Oxford University . *Breaking Barriers to eGovernment Overcoming obstacles to improving European public services 2005-2008* <http://www.egovbarriers.org/>

- Poor technical design: Interoperability blockages caused by incompatibilities between ICT systems or difficult-to-use interfaces to eGovernment services exemplify the kinds of practical flaws that can become serious operational obstacles to take-up of what otherwise appear to be valuable eGovernment systems.

However, actions to overcome these barriers and make possible the role out of e-government services, are already proposed by the e-government action plan and supported by existing programs (e.g. epractices.eu) and no further recommendations are made. Indeed, the action plan aims at:

- Making efficiency and effectiveness a reality : e.g. improve transparency and accountability of government services, lighten administrative burdens,
- Making high impact services for citizens and businesses more available under the EU service Directive 2006/123/EC
- Putting in place key enablers to support interoperability and cooperation
- Developing interfaces between citizens and public institutions
 - Other environmental effects

Other environmental effects have been identified in terms of possible administrative burden reduction, office space reduction, storage space reduction. However these savings would only be significant if the take-up of e-government services is as such as it substitutes for the traditional service and is not provided as an alternative channel.

3.1.2. TELECONFERENCING: AUDIO/VIDEO CONFERENCING

3.1.2.1 Description of teleconferencing and related ICT applications

Passenger transport volumes have followed economic development³⁵⁵, and ICT could provide help in de-coupling transport growth and economic growth by offering alternatives to physical passenger transport. Audio conferencing and video conferencing (i.e. teleconferencing) are two ICT-based practices allowing travel replacement.

- **Audio conferencing**, relies on internet infrastructure, computer/laptops/peripherals, VoiP (voice over the internet protocol), telephone/mobile phone, telecommunication infrastructure
- **Video conferencing**, relies on internet infrastructure, computer/laptops/peripherals, video conferencing rooms (Figure 55), web cameras, microphones, speakers, projector

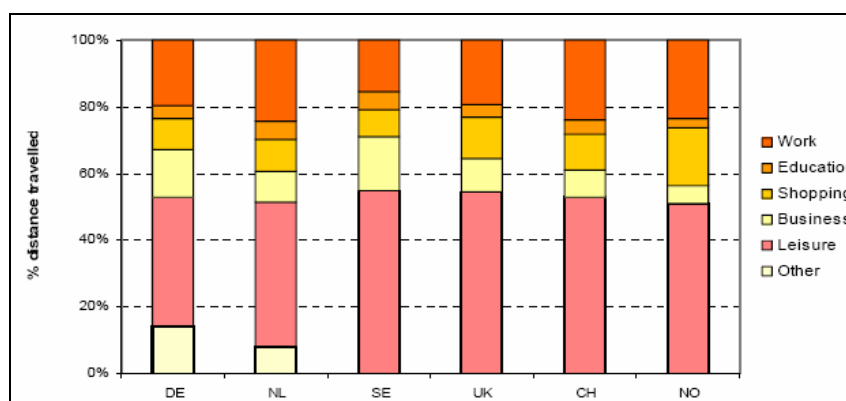
These technologies are both used by individuals and companies. However, this section will focus on the business and industrial sector, and assess the extent of the impact of

³⁵⁵ Between 1990 and 2002, passenger transport volumes in the European Environment Agency member countries grew by 30 % and GDP increased by 27 % over the same period (EEA)

using these technologies which are already allowing reducing the number of business trips³⁵⁶.

In some companies, business travel not only accounts for large expenses but also have a significant environmental impact. For instance, the telecom company Ericsson estimates that 73% of the CO₂ per capita emissions of its Swedish employees originated from business travel³⁵⁷. With total passenger travel via car/rail /air transport in 2005 of 6,245 x10⁹ passenger-km (pkm) in EU 25³⁵⁸, of which between 5 - 15 % can be estimated from business travel (depending of the country³⁵⁹) can be estimated to originate from business travel³⁶⁰. Reducing business travel could provide significant savings in terms of energy consumption and GHG emissions (CO₂ emissions per pkm are approximately 200 g/pkm³⁶¹).

Figure 54: Distribution (%) of distance travelled by purpose of travel³⁶²



³⁵⁶ See case studies in section 3.1.2.3

³⁵⁷ Arnfalk P. *Virtual Mobility and Pollution Prevention: The Emerging Role of ICT Based Communication in Organisations and its Impact on Travel*. 2002 The International Institute for Industrial Environmental Economics, Lund University. 296 p

³⁵⁸ EU DG TREN. European Energy and Transport – Trends to 2030, update 2007
http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/energy_transport_trends_2030_update_2007_en.pdf

³⁵⁹ In some countries like in Sweden business travel can represent up to 13% of total passenger travel (Riks- ResVaneUndersökningen (RVU), Statistics Sweden, 1995)

³⁶⁰ Rough estimate based on Eurostat document "Statistics in focus, Passenger mobility in Europe
http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-087/EN/KS-SF-07-087-EN.PDF

³⁶¹ Based on estimated emissions for aviation and other means of transportation year 2000, in Svenska trafikflygets miljöpåverkan och en jämförelse med andra trafikslag, Institutet för Vatten och Luftvård (IVL), Stockholm, 1996.

³⁶² Eurostat *Statistics in focus, Passenger mobility in Europe*
http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-087/EN/KS-SF-07-087-EN.PDF

Figure 55: Example of a video conferencing unit (HP Halo Room)³⁶³



3.1.2.2 Analysis of the policy framework at EU level, business initiatives, analysis of the e-service status and trends in the EU

■ Status

While no recent data was available to assess the use of video conferencing in the business sector, statistics show that, in 2005, less than 4% of the EU 25 population regularly uses teleconferencing (i.e. either video or audio conferencing) (Erreur ! Source du renvoi introuvable.).

Table 127: Percentage of the population who have used the internet, in the last 3 months, for telephoning or videoconferencing in Europe 2002 – 2005

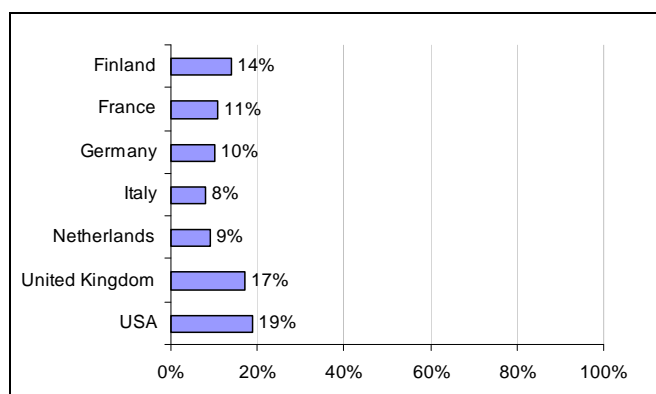
Country	2002	2003	2004	2005
EU 25	N/A	N/A	3.1	3.9
EU 15	N/A	2.5	3.0	3.7

In 1999, data from the ECaTT project shows that less than an average of about 10% of European enterprises uses video conferencing technologies. As more recent data was not available, we make the pragmatic assumption that teleconferencing penetration in EU enterprises was of 10 % in 2005. It can therefore be assumed that there is still room for increase use of these practices in Europe.

Video conferencing units are often installed in regular meeting room, in senior offices or (less often) in dedicated rooms such as HP halo rooms (Figure 55).

³⁶³ <http://www.hp.com/halo>

Figure 56: Use of video conference in European and US establishments (1999)³⁶⁴



■ Policy framework and business initiatives

The following section lists the policies, and business initiatives influencing the deployment of teleconferencing.

Already the existing **EMAS scheme**³⁶⁵ takes into account the effects of transportation of the employees and this tool provides a first step in encouraging organisation in promoting teleconference.

- Within the eEurope 2005 framework, the EU is training its workforce to make full use of ICT.
- Within the existing Communication “**Bridging the broadband gap**”³⁶⁶ represents a strong commitment to providing broadband to all Europeans, also the EU’s regulatory **framework for electronic communications**³⁶⁷ aims at stimulating competition and therefore investment and innovation while increasing consumers’ choice. This stimulates the development of Europe's infrastructure by promoting competition and growth

Business initiatives such as undertaken by the GeSi³⁶⁸, British Telecom, Cisco³⁶⁹, Tandberg³⁷⁰, to communicate on the potential benefits of teleconferencing are already numerous in the ICT sector.

³⁶⁴ <http://www.ecatt.com/>

³⁶⁵ Regulation (EC) No 761/2001 of the European Parliament and of the Council of 19 March 2001 allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS). Official Journal L 114 page 1 on 24 April 2001

³⁶⁶ March 2006 <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006DC0129:EN:NOT>

³⁶⁷ http://ec.europa.eu/information_society/policy/ecomm/current/index_en.htm

³⁶⁸ Karl Otto Schallaböck et al. Digital Europe case study: Telework and sustainable Development A case study with the Global eSustainability Initiative (GeSI) Final Report, April 2003, Wuppertal Institute and Forum for the Future (2003)
<http://www.forumforthefuture.org.uk/files/DigitalEuropeTeleworkcasestudy.pdf>

On a broader scale, the EU transport policies could also influence the deployment of teleconferencing as these technologies offer alternatives to physical passenger transport which could help tackle transport emissions.

■ Trends

It is rather difficult, to estimate the future potentials of teleconferencing in a BAU scenario at EU level, because of the following problems:

- The number of face-to-face business meetings in Europe is unknown and the proportion of these business meetings which could be substituted to a teleconference cannot be quantified.
- The number of events, which potentially might be converted to or realised as some kind of teleconferencing, is not very clear.
- The technical layout and the future availability of advanced teleconferencing are not very clear.
- The potential impact of teleconferencing is not very clear (proportion of business travel which can be substituted by teleconferencing and impacts linked to the use of ICT equipment).

Estimates on future trends therefore need to be documented by the analysis of case studies and will be provided in section 3.1.2.4.

3.1.2.3 Analysis of case studies and assessment of the improvement potential at a micro level

This section presents two case studies related to virtual meetings/teleconferences, providing quantified results in terms of reduction in energy use through transport substitution.

A first insight on the possible environmental benefits and energy savings through the use of virtual meetings is given in Table 128, which shows that the amount of energy used for an hour phone call is equivalent to the energy used when travelling less than 0.5 km in a car. Further details on the possible benefits from virtual meetings are illustrated in the case studies.

The first case study analyses the effects of audio conferencing and was chosen because it provides the most recent and detailed data available (previous studies are available: 2005 and 2006³⁷¹). The second case study focuses on video conferencing and was the only detailed case study found available in literature.

³⁶⁹ Presentation made at the ITU Symposia on ICTs and Climate Change in Kyoto April 2008 http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F0060080018PDFE.pdf

³⁷⁰ Presentation made at the ITU Symposia on ICTs and Climate Change in Kyoto April 2008 http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F0060080005PDFE.pdf

³⁷¹ <http://www.btplc.com/Societyandenvironment/Reports/Reports.htm>

Table 128: Equivalence between a travelled distance and a phone call³⁷²

Type of call	Mode of transport	Distance (km)	Length of time on phone to use equivalent amount of energy
Local	Car	10	21 hours
Trunk	Rail	320	33 days
Trunk	Car	320	7 days
International	Air	5,000	5 weeks

- Case Study: Virtual conferences at UK British Telecom (BT)³⁷³ – Audio conferencing

Context:

SustainIT³⁷⁴, an initiative of UK CEED (Centre for Economic and Environmental Development), focuses on the relationship between ICT and sustainable development and seeks to demonstrate how the ICT technologies can be used to realise these benefits. Current programme partners include the EU Commission, East of England Development Agency, East Midlands Regional Assembly, BT, Brother, Vodafone, Sony, and Hewlett Packard.

Under this initiative, the SusTel (Sustainable Telework) project has provided some of the world's most comprehensive research on teleworking and sustainable development. Also, in this context several detailed case studies are available online, including one on "Conferencing at BT" which was carried out in 2006-2007.

Methodology and assumptions:

In 2007, 6 % of BT's employees (6032 individuals) were surveyed to provide data on their use of virtual conferencing technologies and its impacts on travel, providing a reasonable representation of all conference users at BT³⁷⁵.

Four different types of virtual conferencing technologies are used by BT employees and were surveyed:

- Centrally booked conferences: the traditional form in which a call is booked in advance with a central service and participants are then dialled or dial in themselves (audio conference).
- « MeetMe³⁷⁶ » conferences: users dial into these using the personal code of the conference originator (audio conference).

³⁷² Source: BT (1991). Energy, Telecommunications and the Environment. British Telecom. It should be noted that present conditions differ strongly from the decade-old data, as e.g. optic fibres have lowered energy consumption for telecom transmission dramatically.

³⁷³ http://www.sustainit.org/publications/BT_conferencing_survey_2007_report.doc

³⁷⁴ <http://sustainit.org>

³⁷⁵ Some of the characteristics of those responding to the survey were: 37% were managers, 13% from outside the UK, 30% based in London and the South East of the UK.

- Web conferences: users use the internet to exchange files, notes, etc. whilst also audio conferencing
- Video conferencing: interactive telecommunication technologies which allow two or more locations to interact via two-way video and audio transmissions simultaneously.

Most respondents to the survey had used at least one of these virtual conferencing technologies within the previous month. MeetMe was the most popular (accessed by 94% of employees), followed by web conferencing (45%), and centrally booked conferencing (24%). Video conferencing had only been used by 2% of the respondents.

Characteristics of the last conference call were also asked in the survey showing that 68% of the conference calls lasted for under an hour, and only 7% for more than two hours. Most of the participants were BT staff and 36% of the conferences involved 6 or more locations (average of 5.64 locations) and an average of 9.57 participants. Also, 84% of the conference calls were made from a fixed line and 3% were made using a Voice over the Internet Protocol (VoIP).

Results:

Different types of impacts were analysed in the case study in order to assess the effects of audio-conferencing. First, respondents were asked if they felt that audio conferencing could be considered as a substitute to “face-to-face” meetings. The second step was to quantify the environmental impacts of virtual conferencing in terms of impact on transport and related GHG emission, based on estimates from the employees and on assumptions on the energy use of the ICT equipment supporting audio conferencing.

- Conferencing impacts

When questioned about their last conference call, 42% of the respondents felt that their last conference call had definitely replaced a meeting and 81% stated that conferencing was an essential aspect of their job. Over two third (72%) of the conferencing users felt that their last conference call completely met its objective. Moreover, 71% of those who did not feel that their last conference call met its objectives felt that this was unrelated to the “virtual” nature of the meeting.

- Impacts on travel and GHG emissions, i.e. indirect impacts

Respondents who felt that their last conference definitely avoided a meeting were asked to estimate the distance they would have travelled. **The mean distance (round trip) avoided was estimated to 398 km. Air travel accounted for 48% of the avoided kilometres but only 8% of avoided trips.**

The avoided distance was then converted into equivalent CO₂ emission savings based on 2005 conversion factors from UK Defra. Results show that the average

³⁷⁶ http://www.meetme.bt.com/newusers/docs/whatis_meetme/meetme.htm

saving per round trip is 70 kg CO₂ when considering all modes of transportation, and 45 kg excluding air (see Annexe 2/ Table 177).

Based on these results, it was assumed that the standard savings of 40 kg CO₂ per trip, implying a possible under-estimation (conservative assumption).

During the period of the survey (2006-2007) 2,047,105 conference calls were initiated by BT employees. Based on the results on the conferencing impacts, the study assumed that 42% of these conference calls definitely replaced a meeting, giving a figure of 859,784 avoided meetings.

Based on the average number of location per meeting and on the number of participants (i.e. respectively: 5.68 and 9.57), it was assumed that each avoided meeting resulted in three avoided round trips (conservative assumption), leading to a total of avoided return journeys of 2,579,352; each of them saving 40 kg CO₂.

Under these assumptions, total savings in terms of CO₂ resulting from reduced transport through conferencing at BT were estimated to 103,174 tons of CO₂ in total (i.e. 120 kg CO₂ saved per meeting).

In order to provide a more precise picture of the effects of using ICT for audio conferencing, the direct CO₂ emissions arising from the use of an ICT infrastructure were also estimated.

- Direct impacts

The direct impacts were roughly estimated using the assumptions and calculations detailed below.

In the analysis, it was assumed that the communication medium used for audio conferencing was a broadband line (which is the most electricity intensive medium) using about 0.005 kWh of electricity to run.

Using this rough assumption, it was then calculated³⁷⁷ that each conference call participant, generated 0.00215 kg CO₂ for an average duration of 1 hour per call. Accordingly, the 2,579,352 avoided journeys involved emissions of 5.54 tons of CO₂ (each phone call replaces one journey). Although ignoring the emissions from manufacturing and disposal of ICT equipment, the results show that the direct impacts of conference calls in terms of CO₂ emissions due to use of ICT technology represent 0.0054 % of the CO₂ savings through travel reduction, and they are negligible.

³⁷⁷ Calculations based on electricity emission factors as suggested by UK Defra: 0.43 kg CO₂ per kWh of grid electricity
<http://www.defra.gov.uk/environment/business/envrp/pdf/conversion-factors.pdf>

- Net impacts

Total net savings in CO₂ emission for BT as a whole through audio conferencing were therefore estimated to 103,168.5 tons, i.e. 119.99 kg CO₂ saved per meeting (net savings).

- Financial benefits

Financial benefits from reduction of travel expenses and time saving from reduced transport were calculated. Each conference call was assumed to save 2 hours time for 3 employees and save £148.2 (about €206³⁷⁸). Also, almost 20% of the respondents believed that they would have had to stay overnight for the avoided meeting, and avoided overnights were also taken included in the financial benefits of audio conferencing.

Total savings are estimated to over € 300 million a year for BT as a whole. Precise costs of conferencing within BT were commercially confidential but estimated to about 10-15% of the benefits (see Annexe 2/Table 178).

Discussion of the results and conclusions:

The BT 2007 survey and related calculations show that there is a significant potential to reduce business travel and related emissions through the use of audio conferencing. However, the results are based on self-reported assessments which could not be independently verified and may therefore be under or over estimated. Also, by taking into account only the replies from respondents who felt that their audio conference had definitely avoided a meeting, it excludes a number of calls that might have replaced a meeting. Another important aspect which was not explored is that conferencing may enable more dispersed patterns of working and generate additional travelling in the longer term.

Concerning the direct impacts, the case study shows that they might be negligible compared to the environmental benefits of audio conferencing through travel reduction. However, this was calculated based on very rough assumptions (broadband line using 0.005 kWh) and could be over or under estimated.

To offset these uncertainties, the calculations of the indirect impacts were made using relatively conservative assumptions (i.e. “worst case”).

A previous survey on audio conferencing at BT from 2003, based on the same methodology showed that 22.05 kg CO₂ could be saved per audio conference (compared to 120 kg based on the 2006 survey) due to shorter average avoided distance (i.e. about 151 km compared to about 398 km in 2006). This shows that the

³⁷⁸ Rate at 2007.11.21, 11:42:33 UTC

environmental benefits of audio conferencing highly depend on the avoided travelled distance and on the transportation modes that would have been used.³⁷⁹

Table 129: Summary of the effects of teleconferencing – BT Case study results

Application	Savings from 1 hour Audio conferencing – avoiding 3 journeys			
	Reduced transport (mixed) (km)	Paper consumption (%)	Increased use of ICT equipment	Total savings in kg CO ₂ eq.
Audio conferencing	398 km 3x40 kg CO ₂	No data	0.0054 % of avoided transport CO ₂ emissions	113

- Case Study: Virtual conferences at UK Department for International Development (DFID)³⁸⁰ – Video conferencing

Context:

Within the above mentioned SustainIT³⁸¹ initiative of UK CEED (Centre for Economic and Environmental), a study on the potential economic, environmental and social impacts of video conferencing within the UK DFID organisation were assessed.

The DFID has over 2500 staff in two headquarters (London and East Kilbride, near Glasgow) and 64 offices overseas where about half the staff is employed.

DFID is an internationally located organisation whose activities involve considerable communication between the two headquarters, the headquarters and the international offices, the international offices of the same region. In order to reduce their business travel costs, and to enhance their internal communication, DFID has installed video conferencing units (either in dedicated suites, in meetings rooms or in senior offices). In summer 2006, 30 units were installed in London, 18 at East Kilbride, and around 45 in the major international offices.

Methodology and assumptions:

In early 2006, an independent consulting agency, together with the Sustain IT research centre, was asked to assess the financial, environmental and social impacts of video conferencing activities at DFID. This was achieved through an online survey.

In total, 226 staff people answered at least a few questions of the survey, and 166 persons fully replied, which represents over 6% of all DFID staff.

Moreover, in order to assess the avoided travel, the financial costs and avoided CO₂ emissions through video conferencing use instead of business travel, more specific questions were asked, related to the last conference call of the surveyed staff. These

³⁷⁹ 2003 Conferencing at BT survey

http://www.sustainit.org/publications/files/8-Conferencing_report_2003.pdf

³⁸⁰ James, P. Conferencing at DFID – The Economic, Environmental and Social Impacts, Final report. 2007

http://www.sustainit.org/publications/conferencing_at_dfid_may_%2007.doc

³⁸¹ <http://sustainit.org>

results were then extrapolated to the whole DFID organisation based on the 2005 number of video conferences which amounted to 4,084.

When calculating the overall benefits for DFID, conservative assumptions were used to minimise exaggeration. The detailed assumptions on the avoided travelled distances are explicated in the following section.

Results:

Results presented here primarily focus on the environmental aspects and only briefly present the economic and social impacts of video conferencing.

- User's perception of virtual conferencing

Globally, most users are frequent users of video conferencing (see Annexe 3/Table 179) and have identified positive aspects of conferencing for their work. "Staying in touch with colleagues", "feeling part of a team" were cited among the most important benefits. "Reduced time and stress related to business travel" was mentioned by a third of the respondents. About 23% respondents said that conferencing lead to less effective meetings and to reduced face-to-face contacts, however, these negative aspects seem to be offset by the positive benefits of virtual conferencing and only 3% of respondents gave completely negative responses.

- The last conference call

A majority of 91% of respondents stated that their last conference call was a video conference call.

On average, the conference involved 3.69 locations and 4.43 people (for conferences with 1-9 attendees) and 67% of the respondents answered that their last video conference was completely successful in meeting its objectives.

One major environmental benefit of virtual conferencing is travel reduction. About 37% of the respondents felt that virtual conferencing had reduced their travel and 18% (of 205 respondents) were definite that their last conference had replaced a trip. 41% of this later category of respondents stated the replaced travel would have involved over 13 hours (see Annexe 3/Table 180).

- Extrapolation to the whole DFID organisation – video conferencing

The results related to the "last conference call" were used to assess the impacts of video conferencing at DFID on travel, travel costs and CO₂ emissions. In order to keep conservative assumptions, it was assumed that only one person avoided travelling per video conference call³⁸².

³⁸² However, the survey stated that on average, each conference call involved 3.69 locations and 4.43 participants, which implies the possibility of having more than one person per conference call avoiding travelling

First step was to associate assumptions on the travelled distance avoided per type of trip and travel mode for the 30 individuals who replied that conferencing had definitely replaced a face-to-face meeting and provided details on their avoided trips (see Annexe 3/Table 181).

These results were then averaged among the 205 respondents³⁸³ to the question on avoided meetings, leading to conservative estimates of avoided distance per mode of transport and type of travel per capita.

These ratios per capita were then applied to video conferencing at the scale of the whole DFID organisation using data on the type of video conferences that took place in 2005 (Annexe 3/ Table 182) in order to estimate the savings in terms of reduction of business travel.

The avoided travelled distances were then converted in terms of CO₂ savings using the UK Defra conversion factors already mentioned in the previous case study (see Annexe 3/ Table 177).

- Estimates show that 357 tons of CO₂ equivalent were saved through video conferencing at DFID in 2005 equivalent to 3,254,363.94 km of travel saved (see Annexe 3/ Table 183).
- These savings are however offset by the use of ICT equipment and conference rooms which require electrical energy to operate. The study did not provide detailed data on the energy consumption of the equipment supporting the video conferencing technology. However, the authors estimated that 15% of the savings were offset by the direct impacts of the ICT equipment, leading to total net savings of 303.45 tons of CO₂ in 2005 at the scale of the whole DFID organisation, in other words: 74.2 kg CO₂ savings per video conference (about 797 km).

Travel cost savings were also assessed and estimated to about £535,080 for the whole DFID organisation, i.e. about £131 per video conference³⁸⁴. Further assumptions detailed in the original document lead to total savings of £180 per video conference, when including savings related to travel subsistence and to the benefits of spending less time travelling and therefore more time working.

Discussion of the results and conclusions:

Despite using conservative assumption, the DFID case study reveals that significant savings are achievable through the use of video conferencing as a substitute for face-

³⁸³ This was done by allocating the three types of travel modes: i.e. long haul air/short haul Air and short haul train in the same proportions as those responding that they definitely avoided a face-to-face meetings

³⁸⁴ Equivalent to respectively about € 753,320 and €184.5 (Live rates at 2007.12.03 15:13:26 UTC)

to-face meetings. However, when looking at these results, it should be noted that DFID is an international organisation which require a significant amount of international communication, and that the use of video conferencing in a national organisation would certainly be reduced. Also, the direct impacts of ICT equipment used for supporting the video conferences are only roughly assessed and more data on the impacts of the ICT equipment would be needed for a more complete picture.

Table 130 provides a summary of the potential savings achievable through the use of video conferences as a substitute for business travel.

Table 130: Summary of the effects of virtual meetings in a working environment- results from 2 case studies

Application	Savings from one video conference – avoiding one journey			
	Reduced transport (mixed) (km)	Paper consumption (%)	Increased use of ICT equipment	Total savings in kg CO ₂ eq.
Video conferencing	797 km 87.4 kg CO ₂	No data	15 % of avoided transport CO ₂ emissions	74.2

■ General conclusions on teleconferencing case studies

The two case studies detailed above show that teleconferencing is already allowing reducing business travel. However, the results from these case studies are very company specific and difficult to generalise.

A review of other case studies provided by the literature allows having a broader and more complete analysis of the impact of teleconferencing. Table 131 provides a summary of conclusions on the impact of teleconferencing on transport reported in other case studies. The results suggest the following:

- When teleconferencing takes place, somewhere between **45% and 90% of those involved feel that it reduces their travel.**
- In terms of impacts on **overall company travel, reductions of between 10% and 30% are typically reported for organisations that promote teleconferencing.** It is very likely that the difference (10 versus 30 %) comes from the differences in the composition of the workforce (and its suitability for teleconferencing), although this is very hard to assess.
- Often, travel at peak times, in congested conditions can be avoided.
- The direct impacts caused by the use of ICT equipment is negligible compared to the indirect effects (transport savings)

Table 131: Teleconferencing case studies: impact on transport

Source	Finding
BT (BT c.2001 and Hopkinson et al 2003)	<ul style="list-style-type: none"> 71% of respondents said their last conference call had replaced a meeting (with 52% being 'definite'), whilst 5% stated that it had generated a meeting. 0.5 million car/van trips and 51-59 million miles of travel saved for 108,000 people (approx 5 trips and 450-550 miles per person per year) 46% avoided trips would have taken place during peak periods 10-11% reduction in business mileage
Epson telecentre (SustainIT undated, Bibby 2000)	Telecentre with 8 desks estimated to save 30,000 vehicle miles p.a. (3750 miles per desk).
Mason Williams (2004)	Video meeting equipment meant that travel costs have dropped by a third.
Tetrapak (Arnfolk 2002)	Business travel reduced by 10% due to videoconferencing
Telia (Arnfolk 2002)	Between 1997-2000, business travel by air reduced by over a third, partly due to more virtual meetings (particularly audioconferencing)
Surveys with 4 Swedish companies (Arnfolk 2002)	<ul style="list-style-type: none"> 45-61% respondents said videoconferencing had reduced their own travel 15-25% said it had reduced other people's travel 17-20% said it had only had a minor effect 1-3% said it had increased their travel
Canadian business travellers (Roy & Filistrault 1998)	<ul style="list-style-type: none"> 24.2% said they were travelling less often as a result of company policy to increase utilisation of teleconferencing Of those participating in at least one videoconference in the previous year, users stated that videoconferencing had been a substitute for an air trip in 45% of cases. 1.8% of all business travel may currently be substituted by teleconferencing
Canadian employees (Redekop 1994)	25% respondents made less business trips due to communications technologies in 1992, and 28% in 1994
SCAG meeting (Mokhtarian 1988)	<ul style="list-style-type: none"> Total vehicle miles increased by 29% by replacing a regional meeting for a teleconference, as shorter distances to teleconference facilities were outweighed by increased attendance. Travel in peak-hour, congested conditions was replaced by travel in off peak, less-congested conditions
BT trial 1983-86 (Bennison 1988)	87% of respondents felt that teleconferencing reduced the amount of travel they were making

3.1.2.4 Recommendations and evaluation of the option

■ BAU and Eco-scenario impact analysis at EU level

The case studies provide evidence that the micro level impacts of teleconference are beneficial as they provide a way to reduce business travel.

For the reference year 2005, if we assume that for this reference year about 10 % of companies in Europe practiced teleconferencing (pragmatic assumption based on the ECATT estimate that 10 % of EU enterprises used videoconferencing in 1999); and if savings between 10 and 30 % of business travel are assumed, this leads to a reduction

of between 0.1 % and 3 % of total business travel in Europe through the use of teleconferencing.

Estimates on future trends can be found in literature (Table 132) but provide a very broad range of estimates.

Table 132: Future trends in teleconferencing³⁸⁵

Table 11.10 Future scale and impacts of teleconferencing

Source	Finding
Pye 1976, Goddard & Morris 1976 and Goddard & Pye 1977	44% of meetings could be teleconferenced, including 34% by audioconferencing, and 10% by videoconferencing
Bennison 1988	25% of face to face meetings could have been replaced by videoconferencing
Dodgson et al 1997 and 2000	1997 report argues that, in about 10 years, teleconferencing could replace somewhere between <ul style="list-style-type: none"> • 20% of business travel for 26% of people, and • 20% of all business travel. Their 2000 report only quotes the more conservative estimate.
Apogee Research Inc 1994	Teleconferencing could substitute for 2-11% of business air travel.
Arvai 1991	Teleconferencing could substitute for 12% business air travel by 2005, 25% by 2010 and 35% by 2020
Burger 1995	Videoconferencing could reduce business air travel by up to 40%
Roy and Filiatrault 1998	<ul style="list-style-type: none"> • Proportion of organisations with access to videoconference equipment could be about 60% by approx 2001 • Videoconferencing could replace 15% of business air trips • Videoconferencing was reducing air travel by 2-4% in the short term and could reduce it by 4-9% in about three years
Rapp & Skåmedal 1996	Estimates of the proportion of business travel that teleconferencing could replace are: <ul style="list-style-type: none"> • 30% of Irish business travel (1978 estimate) • 20% of US business travel (1983 estimate) • 20% of Canadian business travel (1983 estimate) • 35% of German business travel (1985 estimate) • 35% of UK business travel (1985 estimate)
Cook and Haver 1994	Teleconferencing could replace 25% of US business travel by air by 2010.
Face2face	50% of business travellers think that videomeetings could be a preferable alternative

Based on these estimates we consider that the **BAU scenario** assumes that in 2020, a proportion of 25 % of EU companies will promote teleconferencing, leading to 10 – 30 % of business travel reduction. This is a conservative scenario, based on the estimate of the proportion of employees expected to be able to use teleconferencing facilities in the future as presented in the study by Dodgson (teleconferencing is seen as viable for 26% of employee surveyed). This scenario is also based on the assumption that the increase in the use of internet and telecommunication technologies³⁸⁶ will lead to an

³⁸⁵ Cairns S, Sloman L, Newson C, Anable J, Kirkbride A & Goodwin P Teleconferencing ‘Smarter Choices – Changing the Way We Travel’ UCL, Transport for Quality of Life Final report to the Department for Transport, The Robert Gordon University and Eco-Logica London, UK (2004)

³⁸⁶ According to EUROSTAT, the share of EU 25 enterprises having access to broadband was of 63 % in 2005 and 80% in 2007.

increase in the number of European companies using teleconferencing technologies (10 % in 2005, 25 % in 2020). It leads to an **overall reduction of business travel between 2.5 and 7.5 % by 2020**.

A **more optimistic scenario** (Eco-scenario) assumes that 50 % companies will promote teleconferencing in 2020, leading to **5 – 15 % of overall business travel reduction by 2020**. A similar scenario targeting a 20 % reduction in business travel by 2050 is used in the ETNO/WWF report on the impacts of ICT on climate change³⁸⁷. The ETNO/WWF reports states that 20 % business travel reduction through videoconferencing would be feasible by 2050, leading to 22.35 Mt CO₂ savings (assuming the roll out of teleconferencing is linear, and starting with a 10 % penetration in 2005 (data from ECATT -), this leads to about 13% reduction in business travel in 2020).

Table 133: Assumptions for potential improvement scenarios (Teleconferencing in 2020)

2020 assumptions	BAU scenario	Eco-Scenario
Share of companies promoting teleconferencing	25%	50%
Improvement in % of reduced business transport (average scenario)	10%	10%
Improvement in % of reduced business transport (high scenario)	30%	30%

These scenarios can then be compared to baseline data provided by data from DG TREN³⁸⁸ which states that passenger transport will reach 7,897 Gpkm in 2020. Of this total passenger transport, **we assume that 10 % is business travel** (789.7 Gpkm).

On the basis of theses assumptions summarised in Table 133, the different BAU and Eco scenarios were calculated and are presented in Table 134.

³⁸⁷ ETNO/WWF. *Saving the Climate @ the speed of light*. October 2006

³⁸⁸ EU DG TREN. Energy and Transport – Trends 2030, update 2007

http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/energy_transport_trends_2030_update_2007_en.pdf

Table 134: BAU and Eco-scenarios for teleconferencing energy savings in business sector

EU Business Transport 2020	Share of companies promoting teleconference in %	Reduction in business travel in % of avoided business travel	Total business transport in Gpkm	Equivalent total business transport in Mtoe ³⁸⁹ (primary energy)	Equivalent Total business transport in Mt CO ₂	Business transport total improvement in %
Baseline [DG TREN 2008 data]	0	0	789.7	27.6	112.5	0
BAU scenario (average)	25	10	770.0	26.9	109.7	2.5%
BAU scenario (high)	25	30	730.5	25.5	104.0	7.5%
Eco scenario (average)	50	10	750.2	26.2	106.9	5.0%
Eco scenario (high)	50	30	671.2	23.4	95.6	15.0%
Average (conclusion)	25 - 50	10 - 30	730.5	25.5	104.0	7.5%

The scenarios show a significant savings potential ranging from 2.5 % to 15 % between BAU and Eco-scenario (respectively leading to 0.7 to 4.2 Mtoe savings) (Table 136).

The impact of transport can be expressed in CO₂ equivalent using emission factors to convert the distance travelled in a certain amount of CO₂. Emission factors depend on the mode of transportation (e.g. car, train, and airplane). For the purpose of our study we propose to use the average emission factors (i.e. related to a mix of mode of transportation) which can be calculated from the case studies presented above (Table 135).

Table 135: CO₂ emission factor

Case study	CO ₂ emission factor (kg/pkm)	Comment
BT (with air)	0.175	Calculated using data from Table 177
DFID with air	0.110	Calculated using data from Table 183
Average	0.142	N/A

This results in an average emission factor of 142.42 g CO₂/pkm, representative of an average mix of transportation modes.

³⁸⁹ Primary Energy estimate based on the Efficiency indicator (toe/Mpkm) provided by DG TREN for the year 2020 for passenger transport : 34.9 toe/Mpkm

Table 136: Reduction of business transport and equivalent savings in various scenarios

EU Business Transport	Business transport savings in Gpkm	Equivalent business transport savings in Mtoe (primary energy)	Equivalent business transport savings in eq. electricity (GWh)(secondary energy) ³⁹⁰	Equivalent business transport savings in Mtoe (secondary energy)	Equivalent business transport savings in Mt CO ₂ taking 0.142 g CO ₂ per pkm
Baseline [DG TREN 2008 data]	0.0	0.0	0.0	0.0	0.0
BAU scenario (average)	19.7	0.7	2,747	0.2	2.8
BAU scenario (high)	59.2	2.1	8,242	0.7	8.4
Eco scenario (average)	39.5	1.4	5,495	0.5	5.6
Eco scenario (high)	118.5	4.2	16,484	1.4	16.9
Average (conclusion)	59.2	2.1	8,242	0.7	8.4

In conclusion, we could assume that regarding teleconferencing in the business sector, an average savings of 8 % of business travel, or about 2.2 Mtoe of primary energy in 2020 is realistic. Considering the average CO₂ emission factor from the case studies (Table 135), these savings are equivalent to about 9 Mt of CO₂.

For the purpose of this study, we evaluate the energy savings in terms of “secondary energy” (e.g. electricity). According to the EcoReport tool³⁹¹: 1 MWh electricity = 10,500 MJ primary energy = 0.251 toe primary energy. Based on this factor, the electricity equivalent to the savings of primary energy can be calculated (Table 136) and then converted into toe unit (11.63 MWh = 1 toe).

In conclusion, in terms of secondary energy, teleconferencing in the business sector, an average savings of 7.5 % of business travel, or about 0.7 Mtoe (=8,242.2 GWh) of primary energy in 2020 is realistic.

The case studies showed that the impacts of increased ICT usage in terms of energy consumption of the IT equipments were negligible and therefore they were not considered in our scenarios.

These results are a little under but still in line with the CO₂ savings announced in the ETNO/WWF report, stating that 20 % business travel reduction through videoconferencing would be feasible by 2050, leading to 22.35 Mt CO₂ savings (assuming the roll out of teleconferencing is linear, and starting with a 10 %

³⁹⁰ According to the EcoReport tool (see footnote below): 1 MWh electricity = 10,500 MJ primary energy = approx. 0.251 toe primary energy

³⁹¹ EuP EcoReport tool is the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC

penetration in 2005, this leads to about 13% reduction in business travel in 2020 – equivalent with ETNO/WWF assumptions to 14.9 Mt CO₂ savings).

■ Recommendations

The European Commission should encourage MS Governments in taking a long term and holistic view of policy to create the right framework for the roll out of teleconferencing.

The main barriers in achieving a large penetration of teleconferencing were identified as the following³⁹²:

- Immaturity of the teleconferencing practice: it takes time for innovation diffusion, acceptance and adoption
- Assumed technical immaturity: belief in a high failure ratio discourages from using the application for important meetings, and with external contacts
- Existing eco-labelling scheme do not to promote substitution of the transportation of people
- The connection between use of the application and environmental savings is not recognised
- Principal problem: the teleconference does not fully replace the physical meeting
- Poor availability - few partners available with access to equipment
- Potential economical and environmental savings not visible
- Existing framework that stimulates, rather than discourages travelling, with travel allowances, and allocation of money for travelling, not for communication
- Several disincentives for the individual, such as reduced professional output, loss of valuable and pleasant experiences, status surrounding business travelling, frequent flyer points and tax-free shopping
- No compensation, or other incentive, for the employee, for replacing the trip by an electronic meeting
- Poor information and control of where teleconferencing facilities are available and how these can be accessed

Most of the recommended actions to overcome these barriers are to be taken at the level of the business organisations (e.g. identify the type of meetings that are the most suitable to replace, make booking and running meetings in this way, equally or more convenient than travelling arrangements, convert the travel policy to a communication policy), however some policy actions can also be suggested

³⁹² Peter Arnfalk, *Information technology in pollution prevention: Teleconferencing and telework used as tools in the reduction of work related travel* IIIIEE, Lund University (1999)

Some suggestions are the following:

- Aiming to reduce the need to travel rather than accepting transport growth, and **addressing transport substitution through teleconferencing and other applications of ICT in the European long term transport strategy** (see next paragraph on e-work). The European Environment Agency (EEA) warned early in March 2008 that existing and proposed measures to reduce transport would not enable the EU to meet its 2020 climate goals. The EEA “TERM” report³⁹³ says emissions of transport will need to be reduced by a further 50 Mt CO₂ eq. over the next decade for the EU to meet its goal. Teleconferencing could possibly contribute the reaching this target enabling 9 Mt CO₂ reductions (Table 136).
- Incorporating very wide bandwidth internet connectivity in new office buildings, to facilitate teleconferencing through the internet
- Providing **financial incentives** to companies that promote teleconferencing as part of their corporate environmental policy

Already the existing **EMAS scheme**³⁹⁴ takes into account the effects of transportation of the employees and this tool provides a first step in encouraging organisation in promoting teleconference.

Further more, **European tools already exist** to ease the roll out of teleconferencing:

- Within the eEurope 2005 framework, the EU is training its workforce to make full use of ICT
 - Within the existing Communication “**Bridging the broadband gap**”³⁹⁵ represents a strong commitment to providing broadband to all Europeans, also the EU’s regulatory **framework for electronic communications**³⁹⁶ aims at stimulating competition and therefore investment and innovation while increasing consumers’ choice. This stimulates the development of Europe's infrastructure by promoting competition and growth.
- Other environmental effects (large scale)

³⁹³ EEA. Climate for a transport change. TERM 2007: indicators tracking transport and environment in the European Union. March 2008

³⁹⁴ Regulation (EC) No 761/2001 of the European Parliament and of the Council of 19 March 2001 allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS). Official Journal L 114 page 1 on 24 April 2001

³⁹⁵ March 2006 <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006DC0129:EN:NOT>

³⁹⁶ http://ec.europa.eu/information_society/policy/ecommu/current/index_en.htm

The Digital Europe case study on Telework and sustainable Development ³⁹⁷ reports that teleconferences mostly substitute business trips that would otherwise be carried out physically. However, a small portion, maybe every fourth or fifth teleconference is reported to trigger additional business trips.

The main argument is that increased use of teleconferencing will stimulate business contacts on a global scale which in turn will stimulate demand for (physical) business trips and the growing distances may override any reduction in the number of trips made.

The study also reports the lack of available data to assess to what extent ICT contributes to the ongoing process of enlarging the geographical scope of business activities, commonly labelled “globalisation”.

3.1.3. E-WORK

3.1.3.1 Description of e-work and related ICT applications

E-work (telework) is a second example of how ICT could provide help in de-coupling transport growth and economic growth by enabling workers to reduce their commute. There is no exact data related to the total passenger transport related to commute, however, it can be roughly estimated to represent around 20 % of the total passenger transport in Europe (see Figure 54).

E-work can also enable other types of savings in terms of reduced office space, but this will be further discussed in the light of a case study in section 3.1.3.3.

E-work can be generally defined as any normal business activity carried out from a remote location by using modern computing and communication technology³⁹⁸. As such, it includes activities such as audio-conferencing and video-conferencing which were already detailed in section 3.1.2. and enable reduced business travel. **However, this section will focus on the aspects of reduced commuting enabled by telework.**

This new way of working is enabled through the use of ICT equipment and technologies such as: collaboration software/tools (e.g. instant messaging services, conferencing services, software for sharing documents and comments with clients, colleagues or business partners, etc.), modems/ISDN adapters³⁹⁹, laptops/peripherals, remote call centre tools (e.g. to transfer calls from the office to the home of the employee),

³⁹⁷ Karl Otto Schallaböck et al. Digital Europe case study: Telework and sustainable Development A case study with the Global eSustainability Initiative (GeSI) Final Report, April 2003, Wuppertal Institute and Forum for the Future (2003)

³⁹⁸ European Commission definition
http://ec.europa.eu/information_society/ecowor/ework/index_en.htm

³⁹⁹ A ISDN adapter (Integrated Service Digital Network) allows digital communication over a conventional phone line

remote LAN access/networking, remote voice/fax/e-mail access, telecommunications services, virtual office support, home/small-area networking, etc.

Distinction is often made between mobile e-workers (i.e. workers who spend a great deal of work with customers outside of the office) and home-based e-workers (most often self-employed e-workers i.e. “internet entrepreneurs”)⁴⁰⁰.

The following paragraphs provide an overview of different practices covered by e-work, as defined in the European ECATT⁴⁰¹ project.

- Home-based telework

Home-based telework is the most commonly known type of telework. It implies a relocation of the workplace, for part or whole of the working time, from the company site to the home of the employee. They can be defined as workers who: work from home at least one full day per week (this threshold is often used to distinguish home-based teleworkers from employees who occasionally bring some work home); use a personal computer; use telecommunications links (phone, fax, - mails) to communicate with their colleagues during work at home; are in salaried employment or self employed but their main working place is at the contractor’s facilities.

- Supplementary telework

Supplementary teleworkers (occasional e-worker) can be defined as home-based teleworkers spending less than a full day at home per week.

- Centre-based telework

Telework centres are establishments that offer workplaces to employees of one or more organisation providing flexible and accessible office space closer to the employees’ homes, or offer services to remote clients. However, the extent of this new concept is difficult to measure.

- Mobile telework

Mobile workers are people who work in a variety of locations, including home and office, and who spend at least 10 hours a week away from their home and their main place of work, e.g. on business trips, travelling or on customer’s premises. This threshold was chosen to exclude occasional travellers.

- Telework by self-employed in SOHOs (Small Office Home Office)

⁴⁰⁰ Distinction seen in Europe's telecoms and electronic communications operators (ETNO) reports, and in the European project : Statistical Indicators Benchmarking the Information Society <http://www.sibis-eu.org/>

⁴⁰¹ *Benchmarking progress on new ways of working and new forms of business across Europe*, ECATT final report, 2000. <http://www.ecatt.com/>

This category includes self-employed persons whose main place of work is at home (i.e. work in SOHO) and who are communicating with their contractors, business partners and clients using ICT.

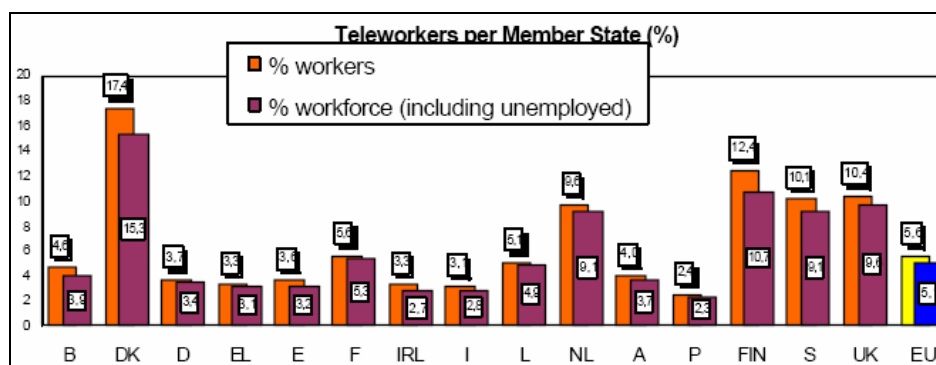
3.1.3.2 Analysis of the policy framework at EU level, business initiatives, analysis of the e-service status and trends in the EU

■ Status

In 1999, the ECATT project reports that 6 % of the EU 10 labour force practises telework.

In 2000, the European Eurobarometer survey on e-work states that about 5 % of workers are teleworkers.

Figure 57: Eurobarometer survey on e-work 2000⁴⁰²



Already in 2003, the SIBIS⁴⁰³ research which uses a broad definition of telework indicates that about 13 % of the European working population (EU 15) can be classified as e-workers with about **7 % practising home-based e-work**; 4% being mobile e-workers and 3.4% being self employed e-workers. This research also reports that in the EU the share of e-workers is considerably higher among the self-employed (21%) than among workers with a contract of employment. The degree of interest is considerable: 40% of the workforce expresses interest in permanent e-work, 52% in alternating e-work and even 55% in centre-based e-work.

As such, there are no exact figures on the amount of telework done in the EU, but estimates say that it amounts to 5-6% of all jobs in the EU for the year 2002, varying from 8% in the Netherlands and the UK to 2% in the Czech Republic and Hungary⁴⁰⁴. There are indications that telework is a rapidly growing phenomenon.

Of course, not all professions show relevant potential for ICT-based telework (e.g. farming and construction). In 2000, the ECATT project indicates that teleworkers are

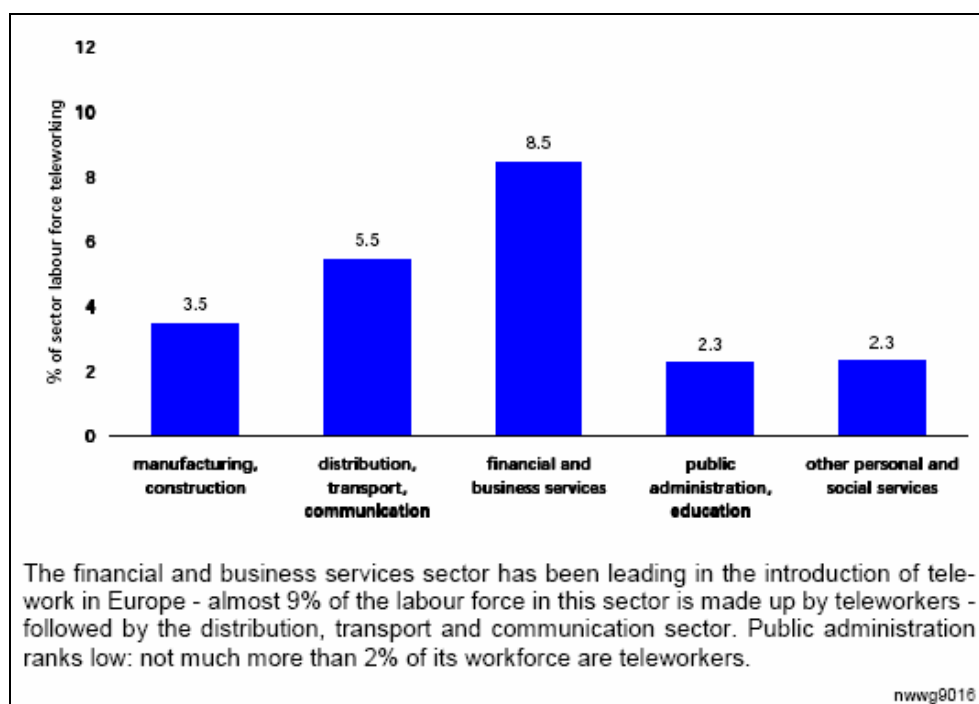
⁴⁰² European e-work 2001 report <http://ftp.cordis.europa.eu/pub/ist/docs/ka2/ework2001.pdf>

⁴⁰³ SIBIS (Statistical Indicators Benchmarking the Information Society) research <http://www.sibis-eu.org/>

⁴⁰⁴ <http://www.etuc.org/IMG/pdf/Telework2006-01429-EN.pdf>

mainly found in the financial and business service and that most of the jobs involved are: IT/programming, distribution and customer services, supportive tasks like data entry and text processing, secretarial tasks, clerical tasks, managerial tasks and positions demanding high levels of qualification. In Germany, a European study reports that 30-35% of all employed persons could be marked as potential teleworkers⁴⁰⁵.

Figure 58: Share of regular teleworkers in industrial sectors EU 10 (2000)



In 2006, about 35% of the companies surveyed in the E-business w@tch report allowed remote access to the company's network with an increase of this percentage along with the company's size. It appears that telework is now mainstream for large companies, but there is a long way to go still for SMEs where many are not yet even aware of the benefits or, indeed, the necessity of introducing new methods of working.

⁴⁰⁵ Digital Europe. *Virtual Dematerialisation and factor X*, 2002,
<http://www.forumforthefuture.org.uk/files/digitaleuropeVirtualdematerialisation.pdf>

Table 137: Internet access and remote access to company network (2006)⁴⁰⁶

	Companies with internet access		Companies with broadband internet access		Share of employees with internet access *		Remote access to company network	
	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms
Total (EU-10)	95	93	76	69	n.a.	43	35	16
By firm size								
Micro (1-9 empl.)		89		62	n.a.	51		12
Small (10-49 empl.)		98		75	n.a.	29		22
Medium (50-249 empl.)		99		83	n.a.	33		43
Large (250+ empl.)		99		84	n.a.	44		60
By sector								
Food & beverages	95	88	72	64	n.a.	25	35	14
Footwear	96	89	75	62	n.a.	28	17	10
Pulp & paper	99	94	80	68	n.a.	40	56	21
ICT manufacturing	100	99	84	79	n.a.	74	69	35
Consumer electronics	98	97	87	74	n.a.	80	51	32
Shipbuilding & repair	100	100	87	86	n.a.	30	41	27
Construction	95	90	72	64	n.a.	47	25	13
Tourism	93	90	72	68	n.a.	53	38	13
Telecommunication	100	99	88	85	n.a.	90	74	46
Hospital activities	100	98	85	78	n.a.	41	39	34
Base (100%)	firms using computers		firms using computers		firms with internet access		firms using computers	
N (for total, EU-10)	7237		7237		6900		7237	

Across sectors, on average 35% of employees in European companies use computers connected to the Internet in their normal work routine. However, there are significant differences in the regular ICT usage across sectors. While the sectors “Real estate, renting and business activities” and “Motion picture and video activities” together with “Radio and television activities” are well above average, “Transport, storage and communication” ranks only slightly above and “Wholesale and retail” on the average. “Manufacturing”, “Construction”, and “Hotels etc.” come up with figures which are clearly below the European average of 35%. In countries for which data is available the sector “Electricity, gas and water supply” appears to also show a performance which is above the European average.

While most companies have access to the internet, the percentage of employees using a computer connected to the internet in their normal work routine is still low. This indicates that there might be a potential for expansion of teleworking-practices.

⁴⁰⁶ E-business w@tch 2006 http://www.ebusiness-watch.org/key_reports/documents/EBR06.pdf

Table 138: Percentage employed using the Internet in normal work routine (2005)⁴⁰⁷

		Manufacturing	Construction	Wholesale/retail	Hotels	Transport	Real estate	Motion picture	Overall performance
EU 25	European Union (25 countries)	28%	23%	34%	25%	39%	55%	68%	35%
BE	Belgium	o	+	+	+	+	+	+	Positive
CZ	Czech Republic	-	-	+	o	-	-	+	Mixed
DK	Denmark	No data	+						--
DE	Germany (including ex-GDR from 1991)	o	-	+	o	+	+	+	Positive/mixed
EE	Estonia	o	+	+	+	+	-	+	Positive/mixed
GR	Greece	No data							--
ES	Spain	o	o	o	o	+	-	o	Average
FR	France								--
IE	Ireland	+	o	-	-	+	o	-	Average/mixed
IT	Italy	-	-	-	-	-	-	-	Negative
CY	Cyprus	-	-	-	o	+	+	o	Average/mixed
LV	Latvia	-	-	-	-	-	-	-	Negative
LT	Lithuania	-	-	-	+	-	-	+	Negative/mixed
LU	Luxembourg (Grand-Duché)	-	-	-	o	-	o	+	Negative/mixed
HU	Hungary	-	-	-	-	-	-	-	Negative
MT	Malta								--
NL	Netherlands	+	o	o	o	+	+	+	Positive/mixed
AT	Austria	+	o	o	-		o	+	Mixed
PL	Poland	-	o	o	+	o	-	+	Mixed
PT	Portugal								--
SI	Slovenia	o	o	+	+	o	o	+	Positive/mixed
SK	Slovakia	-	-	o	-	-	+	+	Mixed
FI	Finland	+		+	+	+	+	+	positive
SE	Sweden	+	+	+	+	+	+	+	Positive
UK	United Kingdom	+	+	-	o	+	o	-	Mixed
BG	Bulgaria	No data	No data	No data	No data	No data	No data	No data	--
RO	Romania	No data	No data	No data	No data	No data	No data	No data	--

-: percentage below European average; +: percentage above European average; o: percentage close to European average

■ Policy framework and current business initiatives

A European “**Framework Agreement**”⁴⁰⁸ on e-work has been reached outlining model telework conditions. Essentially this consists of the following principles:

⁴⁰⁷ Empirica. *Benchmarking in a policy perspective, Report No. 1: e-Business and the Reorganisation of Business Processes*. (2006) for the European Commission
http://ec.europa.eu/information_society/eeurope/i2010/docs/studies/wp2_report_ebusiness_06_04_2_006.doc

⁴⁰⁸ Framework agreement on telework 2002
http://ec.europa.eu/employment_social/news/2002/oct/teleworking_agreement_en.pdf

- voluntary participation and the right of return to work at the employer's premises, unless telework is required in an initial job description
- maintenance of employee status equality of treatment with workers remaining at employer's premises the employer should cover any costs incurred by the teleworking employee
- training rights and opportunities should be guaranteed
- working time should be respected
- the employer is responsible for health and safety in the teleworking environment
- teleworkers should have the same collective rights as workers at the employers premises, and no obstacles are put to communicating with workers representatives.
- personal privacy and data should be protected.

This agreement was negotiated between employers' and workers' representative organisations, and brokered by the European Commission. It does not have the force of a Directive (like the Working Time Directive), but is meant to be a model for use across member states. Some states, like Denmark, already have such national agreements, while some governments like the UK are unlikely to adopt it in any regulatory sense.

On a larger scale, telework is also covered under the **Lisbon strategy** which sets a new strategic goal for the Union to become the most competitive and dynamic knowledge-based economy capable of sustained economic growth with more and better jobs and greater social cohesion. The overall aim is to raise the employment rate from an average of 61 % as close as possible to 70% in 2010 (among the population of working age between 15 and 64 years) and to increase the proportion of working-age women in employment from an average of 51% today to more than 60% in 2010. The **e-Europe Action Plan** was a first step (June 2000), and set targets in 11 areas where coordinated action by Member States was most needed: one of these is in the modernisation of work organisation in a knowledge-based economy. It is now being continued by the i2010 strategy⁴⁰⁹.

The framework described for teleconference in section 3.1.2.2 also provides the policy context for telework.

In many ICT companies, e-work has become a common practice and many case studies exist which can help estimate the potential impact of "flexi-work" in terms of reduction in commute, energy consumption and GHG emission reductions, mainly through the SusTel project (Sustainable Telework – 30 case studies available⁴¹⁰).

■ Trends

⁴⁰⁹ http://ec.europa.eu/information_society/eeurope/i2010/index_en.htm

⁴¹⁰ http://www.sustel.org/d10_d11.htm

A projection of the number of e-workers in Western Europe is given in Table 139 estimating the share of teleworkers to 15% in 2006 and about 17% in 2008.

This estimate is higher than the projection from the European Emergence project⁴¹¹, which estimated the number of e-workers to triple between 2001 and 2010, reaching 27.12 million e-workers in EU 15, i.e. **about 10% of the employed population in 2010**⁴¹².

Table 139: Employed e-workers estimates. Western Europe (1998 – 2008) in millions⁴¹³

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Teleworkers >8hrs/month	5.10	7.45	9.90	12.29	14.50	17.00	19.20	21.00	22.20	23.30	24.28
Growth		46.1%	32.8%	24.1%	18.0%	17.2%	12.9%	9.4%	5.7%	4.9%	4.2%
Teleworkers >8hrs/week	1.63	2.40	3.25	4.07	5.14	6.10	7.17	8.08	8.90	9.60	10.17
Growth		47.2%	35.4%	25.2%	26.3%	18.7%	17.5%	12.7%	10.1%	7.9%	5.9%
EP	143.68	144.11	144.54	144.98	145.01	145.04	145.07	145.10	145.12	145.15	145.18
Penetration of EP >8hrs/month	3.5%	5.2%	6.8%	8.5%	10.0%	11.7%	13.2%	14.5%	15.3%	16.1%	16.7%
Penetration of EP >8hrs/week	1.1%	1.7%	2.2%	2.8%	3.5%	4.2%	4.9%	5.6%	6.1%	6.6%	7.0%

More and more companies are introducing facilities to allow employees to work away from the office.

This trend was confirmed by the Anywhere Office Survey reports that of the 105 IT managers questioned, 93% of them had systems in place to enable employees to work away from their offices. Three quarters of the managers said remote access to email, the use of portable email devices and access to IP telephony were some of the most important applications available⁴¹⁴.

3.1.3.3 Analysis of case study and assessment of the improvement potential at a micro level

The following paragraph analyses the most detailed and recent case study which was available within the SusTel project (Sustainable Telework – 30 case studies available⁴¹⁵).

Case Studies: British Telecom UK (BT 2006)⁴¹⁶

Context:

⁴¹¹ <http://www.emergence.nu/> This study uses a broad definition of telework. The definition of "ework" applied by the EMERGENCE project encompasses any work which is carried out away from an establishment and managed from that establishment using IT and a telecommunication link for receipt or delivery of work.

⁴¹² EUROSTAT population projection in EU 15 and a employment rate of 70%

⁴¹³ EP: Employee population Gartner Dataquest http://www.gartner.com/DisplayDocument?doc_cd=122284#h6

⁴¹⁴ http://www.sustainit.org/news-archive/news_info.php?refnum=1426

⁴¹⁵ http://www.sustel.org/d10_d11.htm

⁴¹⁶ Peter James, Peter Hopkinson. *E-WORKING AT BT - The Economic, Environmental and Social Impacts*, Final report, 24 May 2006. <http://www.btplc.com/Societyandenvironment/Reports/EworkingatBT.pdf>

In order to analyse the prevalence and to create a better understanding of the economic, environmental and social impacts of e-working within the company British Telecom, 5000 randomly selected staff were surveyed in February 2006.

BT is one of Europe's leading providers of telecommunications services and has around 100,000 employees. The company began implementing telework schemes in 1990 and now counts around 11,000 teleworkers formally registered in the Workabout scheme. This voluntary scheme provides equipment and other support to teleworkers who are giving up a permanent BT office space to move to a home-based or mobile working pattern. Three previous surveys (2000-2002) had examined the impacts of this scheme and found generally positive results.

Methodology and assumptions:

BT's environment unit commissioned a survey, focussing on travel impacts of telework.

An online questionnaire was developed to assess not only the environmental impacts (primarily transport) of teleworking but also social impacts, including job satisfaction, and economic impacts. A total of 1054 replies were received out of the 5000 employees surveyed, however, all respondents did not answer all questions and therefore the total number of respondents to one question might vary.

Results:

- Typology of the workers

The seven groups of workers were identified from the survey are the following (Table 140):

Table 140: Identified categories of workers at BT

	Category	Type of worker
a	Office	those answering 'Mainly work at a single BT location, seldom or never work from home'
b	Mobile	all groups other than category a) and office-based, i.e. those who do not work at a single BT location
c	Field	those answering "Work from a variety of locations, but seldom or never from home"
d	E-work	all groups who frequently work from home, i.e. the Agile (see below), Alternate (see below) and Workabout groups
e	Alternate (e-workers)	those answering "Mainly work at a single BT location, frequently work from home" i.e. alternate between working at BT locations and at home
f	Agile (e-workers)	those answering "Work from a variety of locations, frequently work from home (but don't regard this as my office base)"
g	Workabout (e-workers)	those answering "Work from a variety of locations, frequently work from home (and do regard this as my office base)"

A majority of the respondents were office-based, 26% were e-workers of some kind (see Annexe 4/Table 184). The seventh category is called Workabout, because it is the name of BT's scheme for **home-based staff**. It was also the focus of this survey.

- Impacts of transport

Reductions in commuting⁴¹⁷ travel have been reported through the survey.

For e-workers belonging to the Workabout category, the survey reported an average number of avoided commuting days of 2.06 days per week per home-based e-worker based on 64 replies received. When averaged for all 81 Workabout respondents to this section of the survey, this leads to 1.63 avoided days of commuting per week.

The survey also reported average daily reductions of total commuting distance per Workabout e-worker of about 30 miles (50 km) by car and 15 miles (25 km) by train (Annexe 4/Table 185). These savings were converted in terms of avoided CO₂ emissions based on 2005 conversion factors from UK Defra⁴¹⁸ (Department for Environment, Food and Rural Affairs) and are equivalent to 15.20 kg of CO₂ savings per day per Workabout e-worker.

When these savings are applied to all staff registered in the Workabout scheme (11,000 employees), the conclusion of the survey is that 7,691.2 tons of CO₂ per year⁴¹⁹ could be avoided by non-commuting.

- Rebound effects

The travel effects of teleworking very much depend on the typology of the teleworker and some rebound effects are to be taken into account. The survey analyses if reductions in commuting could be offset by increases in personal or in-work related travel.

The survey concludes that home-based e-working through the Workabout scheme does not significantly increase or decrease in-work travel⁴²⁰.

Personal travel can also be affected by teleworking. About 25 % of the Workabout home-based workers stated that they use their car more often for private purposes or let other members of their home use it on the days they are working at home.

⁴¹⁷ The term commuting can be ambiguous, with some researchers defining it as all work-related travel which are paid for by an employer and others, as it has been made in this study, defining it as travel to and from a main office.

⁴¹⁸ i.e. 0.27 kg CO₂ per mile for an average petrol car, 0.29 kg CO₂ for an average diesel car and 0.064 kg CO₂ when travelling by train – see <http://www.defra.gov.uk/environment/business/envrp/pdf/envrpgas-annexes.pdf>

⁴¹⁹ Assuming 46 working weeks per year

⁴²⁰ When asked if e-working had reduced their in-work travel, a majority of Workabout e-workers reported it had remained the same. The number of e-workers stating it had decreased (24 % stating it had decreased their work related travel of about 103 miles) was exactly equal to the number of respondents stating it had increased (24% stating it has increased their work related travel of 99 miles).

The survey concludes that if these results are extended to all 11,000 registered Workabout workers, emissions of 2,231.5 tons of CO₂ per year⁴²¹ could arise from additional car trips for personal purposes. Detailed results are provided in Annexe 4/Table 186.

Rebound effects can also occur when e-workers undertake **extra journeys** which were previously made in conjunction with commuting (e.g. shopping, transporting children, etc.). About half of the Workabout workers (53%) reported no extra journeys while the other half reported so. According to the survey, a total of about 1,796 tons of CO₂ per year⁴²² arise from special journeys that would otherwise be undertaken in conjunction with commuting when considering all 11,000 registered Workabout employees (see details Annexe 4/Table 187).

- Net impacts

Considering the travel related avoided emissions and rebound effects the net savings totalled among the 11,000 Workabout registrants are equal to 3663.2 tons CO₂ per year (Annexe 4/Table 188). This is equivalent to net savings of 7.24 kg CO₂ per week per e-worker. These results suggest that 52% of the initial commuting savings are preserved even after rebound effects are taken into account.

- Work practices and technologies

Interesting results from the survey shows that about 45% of all e-workers and only 7% of all Workabout e-workers keep a dedicated office space in one BT location.

One point which is sometimes made about e-working is that it can lead to increased printing, because people often have duplicate copies of documents in different working locations. However, BT in general is rather on the way to reduced office paper consumption. While not exact quantification is available, more respondents feel that it has decreased (37%) rather than increased (21%). The ratio is even greater for e-workers (51% to 16%) and suggesting that e-working leads to less rather than more printing. Reasons for this might be putting many tasks, such as expenses claims or purchasing, online; and provision of broadband access to the Internet and BT Intranet to most e-workers. Both create a high level of reliance on, and trust in, electronic media to have information available when required, so that printing is not necessary.

Most e-workers do have access to DSL broadband at home. However, despite their communication-dependent working practices, newer appliances or applications such as Blackberry, VOIP or 3G have not yet achieved a high level of usage even in a forefront company of the ICT sector such as BT (see Annexe 4/Table 189)

⁴²¹ Assuming 46 working weeks per year

⁴²² Assuming 46 working weeks per year

Social and economic impacts are discussed in Annexe 4/Box 2.

Discussion of the results and conclusions:

The UK BT 2006 survey reports that e-working could significantly reduce transport related environmental impacts and also reduce paper use. However, other environmental implications need to be considered to assess the full potential of teleworking such as:

- reduced need for office space,
- increased need for space at home/local centres,
- increased/change (e.g. from a PC to a laptop) need for office equipment and telecommunication .

In relation with the two first issues, the shifted need for office space from the office to the home could have a variable effect on the energy consumption for heating/cooling/lighting of the e-worker, depending on his typology (i.e. purely home based, part time home-based, or working from a local office).

As the energy required for heating, ventilation, lighting etc. of homes and workplaces makes up a significant part of our total energy consumption (see Annexe 1/Box 3), it is important to estimate if the need for office space is reduced or not. A flexible office space can accommodate the same number of persons in a much smaller office area, thus saving high costs of office space for the organisation. If this teleworking scheme is put in place, additional energy savings can be expected.

Up to now, only a small minority of all offices have been reorganised into fully flexible offices (see details Annexe 1/Box 4). Consequently, most offices are empty during the time an employee teleworks and no office space reductions are observed. However, in the UK BT survey, it was reported that only 7% of Workabout employees kept a desk dedicated to their use in their office. Another 25% used a “hotdesk” (shared desk with another team member) and 27% used a “flexi-desk (bookable workstation) instead.

In UK and USA, the average amount of energy needed to heat, light and , air condition and service offices has been estimated to be around 2,000 kWh per traditional worker per year.⁴²³

- Assuming that similar energy savings through office space reduction are enabled by half of the UK BT teleworkers for which detailed data on the average number days working at home was available (i.e. 1.63 per week), it can be estimated that savings of about 77,956.5 kWh⁴²⁴ per week could be achieved among the Workabout participants. Using the electricity conversion factor for CO₂ emission from UK Defra, this would be equivalent to an additional saving of 33.52 tons CO₂ per week (1,542

⁴²³ Gray, M & Hodson, H. *Teleworking Explained*, 1993 John Wiley & Sons

⁴²⁴ = $0.5 \times (1.63 \times 2,000 / (46 \times 5)) \times 11,000$ assuming 5 working days a week, and 46 working weeks a year

tons per year for all 11,000 Workabout e-workers, i.e. additional CO₂ savings of 3.05 kg per week per e-worker on average and 6.09 kg CO₂ (i.e. 14.17 kWh) per e-worker giving up his dedicated workspace)).

- However, these savings would be offset to about additional 244.5 kWh⁴²⁵ per year electricity use due per e-worker to longer home occupation while e-working at home. Estimating that all Workabout registrants spend 1.63 days a home, it can be estimated that about 58,467.4 kWh per week could be additionally consumed in their homes. Using the electricity conversion factor for CO₂ emission from UK Defra, this would be equivalent to additional emissions of 25.14 tons CO₂ per week (i.e. 1156.5 tons per year for all 11,000 Workabout e-workers, i.e. additional CO₂ emissions of 2.28 kg (i.e. 5.31 kWh) per week per e-worker).
- Net effects of e-work on the energy consumption for lighting, heating and cooling would then be equal to savings of 386.7 tons CO₂ per year, i.e. 0.76 kg CO₂ per week per e-worker considering half the e-workers give up their dedicated office space. These savings could be higher assuming all workers give up their office space, reaching 3.80 kg CO₂ per week per e-worker.

Table 141 provides a summary of the results from the 6 surveys conducted in the SusTel study, and more specifically from the UK BT case study.

Table 141: Summary of the effects of telework – Results from the BT 2006 case study and rough estimates

Application	Annual savings for one teleworker spending 1.63 days at home per week					
	Transport car (km) (net savings)	Transport train (km) (net savings)	Paper consumption (%)	Net electricity consumption savings for heating/cooling/lighting office space and home (kWh)	ICT equipment	Total Net savings in kg CO ₂ eq.
Home based telework – with office space reduction	1495	1850	No data	407.5	No data	520.6
Home based telework – without office space reduction	1495	1850	No data	-244	No data	228.7
Home based telework – “average”	1495	1850	No data	81.75	No data	374.6

In this case study, the direct environmental impacts of the ICT equipment is not assessed. However, previous studies show that these impacts are negligible in comparison with energy savings from commuting reduction and reduction of office space (Annexe 1/ Figure 93) and we can assume the results would not be significantly affected by these direct effects.

⁴²⁵ AT&T company data – see details in Annexe 3/ Box 2

3.1.3.4 Recommendations and evaluation of the option

■ BAU and Eco-scenario impact analysis at EU level

The BT 2006 case study shows that e-working can enable energy savings through reduced commuting and reduced office space at the scale of one teleworker, and at the scale of one company.

In this section, the approach is to extrapolate the savings related to one teleworker (see Table 141) in order to estimate the benefits of teleworking at the scale of the whole EU-27, in a BAU scenario and in an Eco-scenario.

This approach can be challenged as it misses some of the synergetic effects that could result from a large scale implementation of telework in Europe (discussed later in the paragraph on the large scale rebound effects, p.116). However, it still provides an estimated forecast of the benefits of telework which can serve for comparative purposes (e.g. to compare telework and teleconferencing).

For the BAU scenario, based on the estimate that 5.1 % of the employed population consist of e-workers⁴²⁶ in 2000, and on **the projection that 10 % of workers will be e-workers in 2010**⁴²⁷, the share of e-workers in 2005 and 2020 was calculated using a linear extrapolation, leading to 7.5 % of total employees being e-workers in 2005 and about 20 % in 2020.

For the Eco-scenario, we assume that in 2020 all the workers interested in e-working actually become teleworkers. According to the 2001 Eurobarometer survey on e-work, 26 % of employed population is interested in teleworking and therefore we assume that about **25 % of the workers are e-workers in 2020**. For the year 2010, we assume that about 15 % of the employees are teleworkers.

The assumptions on the share of teleworkers are summarised in Table 142. The number of e-workers was calculated based on basic data on employment and trends until 2030 provided in Table 144.

Table 142: Future trends in e-work BAU and Eco-scenario until 2020

Status and trends	2000	2005	2010	2020
BAU-scenario				
Share of e-workers in total workforce	5.10%	7.55%	10%	20%
BAU-scenario				
Number of e-workers (1000)	10,657	16,302	24,155	46,397
Eco-scenario				
Share of e-workers in total workforce	5.10%	7.55%	15.00%	25.00%
Eco-scenario				
Number of e-workers (1000)	10,657	16,302	36,232	57,996

⁴²⁶ European Eurobarometer survey 2000, see Figure 57

⁴²⁷ European Emergence project estimate for EU-15 in 2010 – We make the pragmatic assumption that this share is the same for EU-27. <http://www.emergence.nu/>

For each of these scenarios (BAU and Eco), we then assume two sub-scenarios: one “average scenario” where it is assumed that no office space reduction is taken into account, and one “high scenario” where it is assumed that half of the e-workers give up their office space (see Table 143).

Table 143: Assumptions for potential improvement scenarios (e-work 2020)

E-work in EU 27 2020 situation	Share of e-workers among workforce in %	Share of e-workers who give up their office space in %
BAU scenario (average)	20	0
BAU scenario (high)	20	50
Eco-scenario (average)	25	0
Eco-scenario (high)	25	50

The **basic data related to the total number of employees in EU 27** is based on data from Eurostat⁴²⁸ and from the EU Directorate General for Employment⁴²⁹, Social Affairs and Equal Opportunities (data underlined in Table 144).

Additional assumptions were made to estimate the complementary baseline data on employment.

Complementary data for the years **2010 and 2030** were calculated assuming that:

- The rate of employment among the population aged 15-64 reaches 70% in 2010 (Lisbon target) and remains at this level until 2030 [allows calculating the Population in employment aged 15-64]
- The ratio of the Population in employment aged 15-64 over Total employed population is constant until 2030 and equal to the 2005 ratio (=95.83%) [allows calculating the Total employment]
- **Data for 2020** was then calculated based on a linear extrapolation between 2010 and 2030.

⁴²⁸ Eurostat – Statistics in focus 2006, Long term population projections at national level

http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NK-06-003/EN/KS-NK-06-003-EN.PDF

⁴²⁹ Employment in Europe 2007 report available at

http://ec.europa.eu/employment_social/employment_analysis/employ_en.htm

Table 144: Basic data on employment and trends until 2030

EU 27 basic data on employment	2000	2005	2010	2020	2030
Total population (000)	474389	483568	493566	496400	494784
Population aged 15-64	319355	325687	330690	317597	304504
Total employment (000)	208964	215920	241548	231984	222421
Population in employment aged 15-64	198720	206923	231483	222318	213152.8
Employment rate among 15-64	62.23%	64%	70%	70%	70%
Share population employed	44.05%	44.65%	48.94%	47%	45%
Ratio population aged 15-64/ Total Population	67.32%	67.35%	67.00%	64.27%	61.54%
Ratio population employed 15-64/ Total employed population	95.10%	95.83%	95.83%	95.83%	95.83%
<p>Underlined: Eurostat⁴³⁰ and the EU Directorate General for Employment⁴³¹, Social Affairs and Equal Opportunities data</p> <p><i>Italics:</i> calculated based assumption on rate of employment among the population aged 15-64 is 70% in 2010 (Lisbon target) and remains at this level until 2030 and that ratio of the Population in employment aged 15-64 over Total employed population is constant until 2030 and equal to the 2005 ratio</p> <p>Data for 2020 = linear extrapolation of data for 2010 and 2030</p>					

On the basis of the assumptions summarised in Table 143, the different scenarios for e-working in Europe were calculated and the results are presented in Table 146 and Table 147.

The impact of transport and reduced energy use are expressed in equivalent CO₂ emission (Table 146) or in toe (tonne oil equivalent) (Table 147). The conversion factors and emission factors used in the calculation are presented in Table 145.

Table 145: Emission and conversion factors used

Emission and conversion factors	2005	2020	Source
Passenger transport efficiency indicator (toe/Mpkm)	37.5	34.9	DG TREN
CO ₂ emission factor CAR kg/pkm	0.181	0.181	ECOIVENT 2.0. average European – assumes no change 2005/2020
CO ₂ emission factor TRAIN kg/pkm	0.0151	0.0151	ECOIVENT 2.0. average European – assumes no change 2005/2020
CO ₂ emission factor electricity kg/MWh	458.21413	458.21413	Eco Report – assumes no change 2005/2020
Conversion factor (Primary energy/electricity)	1 MWh electricity = 10500 MJ primary energy = 0.251 toe		EcoReport
Conversion factor (MWh/toe)	11.63	11.63	IEA

⁴³⁰ Eurostat – Statistics in focus 2006, Long term population projections at national level

http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NK-06-003/EN/KS-NK-06-003-EN.PDF

⁴³¹ Employment in Europe 2007 report available at

http://ec.europa.eu/employment_social/employment_analysis/employ_en.htm

Table 146: BAU and Eco-scenario for e-work – Net savings in CO₂ equivalent

2020	Net savings in Gpkm (car)	Net savings in Gpkm (train)	Net savings through office space reduction vs. increased home occupation GWh	Equivalent net savings in Mt CO ₂ (car)	Equivalent net savings in Mt CO ₂ (train)	Equivalent net savings of office space reduction vs. increased home occupation in Mt CO ₂	Total net savings in Mt CO ₂
BAU scenario (average)	69	86	-11,344	13	1	-5	9
BAU scenario (high)	69	86	3,781	13	1	2	16
Eco-scenario (average)	87	107	-14,180	16	2	-6	11
Eco-scenario (high)	87	107	4,727	16	2	2	19
Average							14

Table 147: BAU and Eco-scenario for e-work – Net savings in Mtoe

2020	Equivalent savings in Mtoe (car) (primary energy)	Equivalent savings in Mtoe (car) (primary energy)	Equivalent savings in eq. electricity (GWh) (secondary energy) (car) ⁴³²	Equivalent savings in eq. electricity (GWh) (secondary energy) (train) ⁴³²	Equivalent net savings in Mtoe (train) (secondary energy) ⁴³³	Equivalent net savings in Mtoe (train) (secondary energy) ⁴³³	Equivalent net savings through office space reduction vs. increased home occupation in Mtoe ⁴³³	Total net savings in Mtoe
BAU scenario (average)	2.4	3.0	9,653.4	11,967.4	0.83	1.03	-0.98	0.9
BAU scenario (high)	2.4	3.0	9,653.4	11,967.4	0.83	1.03	0.33	2.2
Eco-scenario (average)	3.0	3.8	12,066.7	14,959.3	1.04	1.29	-1.22	1.1
Eco-scenario (high)	3.0	3.8	12,066.7	14,959.3	1.04	1.29	0.41	2.7
Average								1.7

The scenarios show significant savings from 9 to 19 Mt CO₂ (i.e. between 0.9 and 2.7 Mtoe). **In conclusion, we could assume that average savings of 14 Mt CO₂, or about 1.7 Mtoe are realistic in 2020.**

These savings can be compared to baseline data from DG TREN⁴³⁴.

This shows that **in terms of transport savings**, due to reduced commuting, e-working leads to a **1.97 % reduction in total passenger transport in a BAU scenario**, and to a **2.46 % reduction in total passenger transport in an Eco-scenario**.

Assuming about 20 % (rough assumption, only to provide an idea of the magnitude) of total passenger transport is due to commute, this leads to **9.8% and 12.3% reduction in commute respectively in a BAU and Eco scenario**.

In terms of savings related to office space reduction, compensated by increased home occupation, they represent about **-0.33 %** (negative savings = increase) of total residential and commercial HVAC/lighting when it is assumed that all e-workers keep

⁴³² Calculated based on the EcoReport factor : 1 MWh electricity = 10500 MJ primary energy = 0.251 toe primary energy

⁴³³ According to IEA 11.63 MWh = 1 toe (secondary energy)

⁴³⁴ EU DG TREN. Energy and Transport – Trends 2030, update 2007

http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/energy_transport_trends_2030_update_2007_en.pdf

their office space, and about **0.11 %** of total residential and commercial HVAC/lighting when it is assumed that half e-worker give up their office space.

Table 148: Baseline data from DG TREN related to passenger transport and buildings

Baseline data for 2020	2020
Passenger transport	Gpkm
Total passenger transport	7897
EU Energy Consumption	
Residential by use	Mtoe
HVAC	215.0
Lighting	15.0
Total	230.0
EU Energy Consumption	
Services by use	Mtoe
HVAC	92.5
Lighting	6.0
Total	98.5

■ Recommendations

The main barriers to the roll out of telework have been identified as the following:

- Accessibility of personal information from homes: for example, in the banking sector the development of virtual call centres may be held back by data security concerns. Security concerns would also seem less relevant for the insurance sector. High demands for security hinders remote connection to the main workplace's server;
- Commuter traffic is not seen as an environmental issue concerning the organisation;
- Not everyone is suited for this kind of remotely managed work (because of self-discipline; family situation, inclination for stress etc.) and all types of work are not suited for telework;
- Reduced career opportunities;
- Laws controlling taxation for EEE equipment, deduction for workspace at home; tax reduction for commuting;
- Telework gives no savings when buying monthly seasons tickets;
- Poor availability of information electronically;
- The physical space at home may not be suitable for telework.

The main recommendations on how to overcome these barriers are the following:

- **Provide information and guidelines:** Information and advice about teleworking could be included as part of any initiative aiming to influence commuter travel, including the literature relating to travel plans. Also, more education and guidance about what constitutes telework could be of benefit. Currently, it is often taken as having people working at home five days a week. However, many organisations with successful

telework strategies offer employees a more flexible range of options, for example, the chance to work at home one-day a week or to use satellite offices on occasion. Finally, the social benefits of teleworking (e.g. better work life balance) could be more widely disseminated. An example of a booklet providing guidelines on how to introduce telework in organization is given by a Belgium publication⁴³⁵ (supported by the EC).

- As already mentioned when assessing the impacts of teleconferencing, aiming to reduce the need to travel rather than accepting that transport growth, and **addressing transport substitution through teleconferencing and other applications of ICT in the European long term transport strategy** could be an option to consider. Teleconferencing could possibly contribute to reaching the European transport emission reduction target enabling 14 Mt CO₂ reductions (Table 146).

Research in telework has already been performed (e.g. European Emergence project, Elite Project), however, there is still a need for more reliable statistics for tracking the development of individualised e-work in Europe and also for collecting data on best practices and achieved benefits through e-work.. Other recommendations in order to overcome the lack of use include:

- Requiring employers to take more responsibility about how their employees commute could help to facilitate more sustainable commuter travel (including, probably, helping to stimulate telework). The **EMAS scheme** provides a first step in encouraging an organisation in reducing its travel-related impact, including generated through commute.
- Local authorities could be encouraged to lead and show the way.
- Demand management policies for car use, such as road pricing, fuel duties, workplace parking levy and congestion charging, are all likely to encourage more sustainable commuter travel.
- Either government or local authorities could potentially encourage teleworking through grants to businesses, to help meet the initial costs of establishing a teleworking programme, perhaps as part of workplace travel plan programmes.
- There may also be a role for tax breaks – for example enhanced capital allowances to establish telework centres.

■ Other environmental effects (large scale)

A large scale implementation of telework could generate the following environmental effects:

- Teleworkers tend to live further away from their work place; therefore a longer travelled distance could compensate the savings of a reduced number of commute.

⁴³⁵ Clés pour introduire le télétravail dans une entreprise (septembre 2007)
<http://www.emploi.belgique.be/WorkArea/showcontent.aspx?id=12540>

- Reduced car ownership as households have less need for a second car because of teleworking

However, no data was available to quantify the impacts of such effects.

3.1.4. DEMATERIALISATION OF MATERIALS AND SERVICES

This section covers all processes whereby the use of ICT technologies allows a physical product or service to be replaced by a digital product (e-goods) or an online service. Some of the main applications (current, near future) of dematerialisation through the replacement of physical products and services by online services or digital products are presented in the paragraphs below.

A lot of these e-goods are enabled by the potentiality of ICT to reduce the amount of paper-based documents and transportation needs.

Preliminary conclusions on the possible environmental benefits of such digital goods and services indicate that purely digital distribution of e-goods is clearly beneficial from a material intensity point of view, compared to the physical products. However this remains valid only under the assumption that the user does not proceed to the rematerialisation of the digital goods (e.g. burn music on a CD).

3.1.4.1 E-ticketing/ Mobile ticketing

- Description of e-ticketing/ mobile ticketing and related ICT applications

- E-ticketing

E-ticketing is the replacement of paper-based tickets by an “electronic ticket” sent via e-mail.

This practice can be applied to all types of tickets, and reservations for all types of entertainment, events, and transport systems, etc.: e.g. music concerts, theatre show, soccer games, rail tickets, airline tickets, movies, etc.

Some of the advantages and drawbacks of e-tickets are presented in Table 149. Among aspects which could improve the energy efficiency of the ticketing process figure: paper consumption reduction, elimination of postal delivery, and elimination of the need to go to a travel agency. However, it should be kept in mind that e-ticketing allows airline companies to save money and to propose more attractive prices which attracts more and more customers and travellers, increasing air traffic (specifically in the case of low cost airlines). Most of these benefits of e-ticketing in the airline industry could be also extended to the other activities mentioned above (e.g. music concerts, movies, rail tickets, etc.).

Table 149: Advantages and Disadvantages of e-ticketing⁴³⁶

Advantages	Disadvantages
CUSTOMERS <ul style="list-style-type: none"> - Safety. Unable to 'lose' e-ticket. - Speed. Eliminates wait for postal delivery, and physical check-in. - Able to modify/change flight itinerary without need to issue new paper ticket. - Ability to independently access customer profiles/loyalty points information. 	<ul style="list-style-type: none"> - Relatively new technologies – possibility of system failures. - Increased risk of user error, with greater consequence of error. - Higher risk of letting tickets be unused (mainly corporate clients).
AIRLINES <ul style="list-style-type: none"> - Reduction in paper printing and distribution costs. - Elimination of costly intermediaries. - Faster accounting and revenue processing. - Decrease in labour costs. - Greater efficiency at check-in desks. Reduction in check-in labour. - Greater opportunity to strengthen customer bonds. 	<ul style="list-style-type: none"> - Still new technologies – acceptance levels within public? - e-ticket fraud - Difficulty with identify verification - Inability to support multi-line travel - Warsaw Convention liability legislations (passengers are legally required to be given a 'Notice' for travel)
TRAVEL AGENTS <ul style="list-style-type: none"> - Reduced dependence on geographical proximity to clients. - Reduction in ticket postal costs. - Greater productivity. 	<ul style="list-style-type: none"> - Loss of commission revenue from airlines. - Inability for e-ticketing to handle complex itineraries. - Investments in training.

E-ticketing can also be found in the shape of contact less smart cards, and is often used in public transportation systems (e.g. Paris Metro, London Tube).

- Mobile ticketing

The next step in the evolution of electronic ticketing will be to replace tickets with an electronic ticket that can be sent to a mobile phone or PDA via short message service (SMS) (Figure 59). This mobile ticket (m-ticket) consists of a bar code that can be quickly read and validated directly from the mobile device's display screen (Figure 60).

⁴³⁶ Hoosain & Kahn 2000, www.iata.org, www.Swiss.com

Figure 59: The different steps of mobile ticketing⁴³⁷

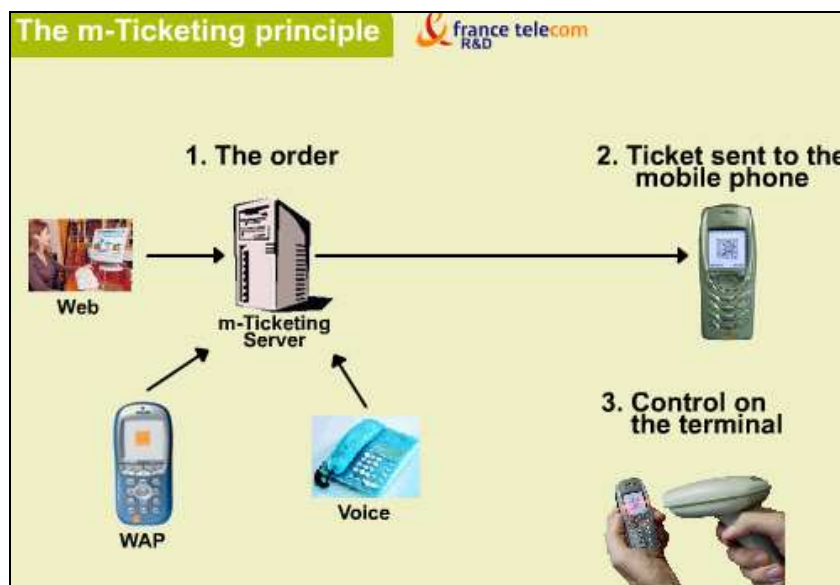


Figure 60: Electronic ticket on a mobile phone (2D barcode)⁴³⁸



Mobile tickets can also be found in the shape of RFID technology called near-field communications (NFC) embedded in a mobile phone (NFC chip could be attached to a mobile phone or imbedded in a phone's SIM card). This technology is particularly adapted to the public transport industry (Figure 62) and converges with the contact less smart card technology (Figure 61).

⁴³⁷

France

Telecom

<http://www.francetelecom.com/sirius/rd/en/ddm/en/technologies/ddm200405/techfiche4.php>

⁴³⁸ *Ibid.*

Figure 61: Convergence of mobile and electronic ticketing in public transportation⁴³⁹

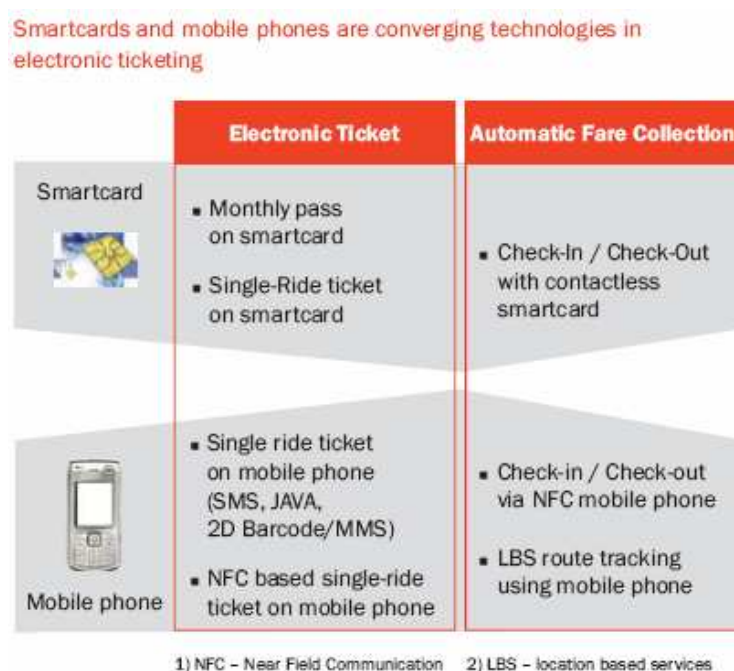
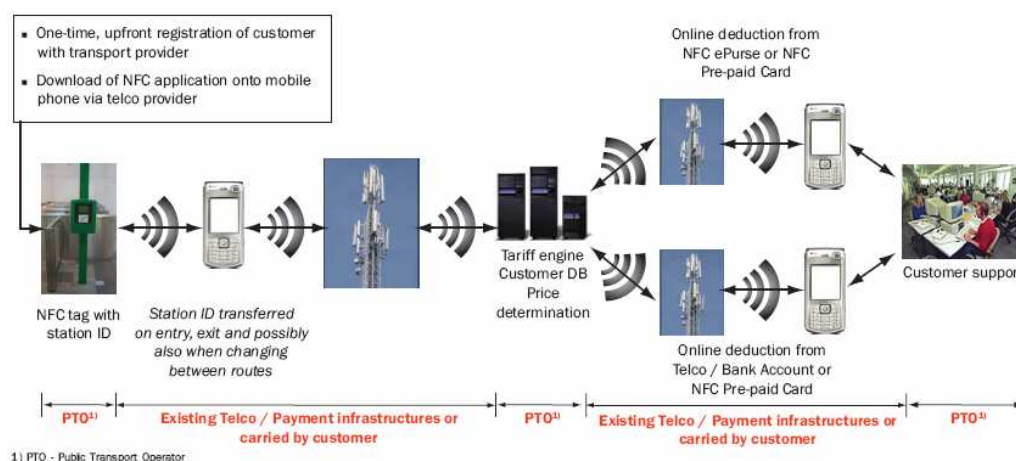


Figure 62: NFC based mobile-ticketing⁴⁴⁰

How "Active NFC"-based Automatic Fare Collection in mass transit works



The ability of mobile ticketing to reduce costs, improve customer service and improve ticket validation efficiency will make it an increasingly attractive option for concerts, parking, sporting events, movie theatres, theme parks, trains and other public transportation.

⁴³⁹ Booz Allen & Hamilton. Next Generation e-ticketing, March 2007.

http://www.boozallen.com/media/file/Next_Generation_eTicketing.pdf

⁴⁴⁰ ibid

- Analysis of the policy framework at EU level, business initiatives, analysis of the e-service status and trends in the EU

- Status

E-ticketing is very widespread in the airline industry where a 2007 worldwide survey performed by the International Air Transport Association (IATA) reported that 88% of passengers prefer electronic tickets over paper tickets. After emerging in the mid-1990s, electronic tickets now account for about half of all tickets issued worldwide, according to IATA. In the United States and parts of Europe, they are especially bought by business travellers. And they will become the standard everywhere else by 1 Jan 2008, IATA members insist, or non-compliant airlines would lose access to IATA's 60,000 accredited travel agencies. The leaders at the International Air Transport Association were at first convinced that the airline industry could achieve global e-ticket ubiquity by May 31st 2008 but revised the target to 96.5% because of interline journeys (itineraries that involve more than one airline) that will remain paper ticket based due to the absence of an interline e-ticket agreement, also, they estimate that about 1% of tickets will be paper tickets as per the choice of the travel agents, and about 0.1% will be accounted for airlines who choose not to introduce electronic ticketing at all.

E-ticketing could be also extended to other activities mentioned above (e.g. music concerts, movies, rail tickets). However, this section will not assess the current extent of e-ticketing in these various sectors due to unavailability of solid data. An indication is that, e-commerce still represents a low proportion of the overall trade turnover (2.7%, 2.8% and 4 % in EU 25 respectively in 2004, 2005, and 2006 according to EUROSTAT⁴⁴¹) and that B2C e-commerce represents an even smaller share of the total trade turnover. Based on data from the 2002 SIBIS survey, it can be assumed that the share of B2C online sales over total B2C sales is around 5% in Europe⁴⁴².

For **contact less smart cards**, was estimated that the total volume of smart cards in electronic ticketing use in European urban mass transit in 1999 was about 885,000. This total was estimated to rise to 45.2 million over the next four years (2003)⁴⁴³. In London, there are currently 10 million smart cards for about 8 million passenger trips per day⁴⁴⁴.

⁴⁴¹ EUROSTAT Percentage of enterprises' total turnover from E-commerce via Internet in EU 25
http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=Yearlies_new_science_technology&root=Yearlies_new_science_technology/I/I5/ir080

⁴⁴² SIBIS <http://www.sibis-eu.org/statistics/data/3-25.htm>

⁴⁴³ UK Datamonitor http://findarticles.com/p/articles/mi_m0GYN/is_8_2/ai_57633891

⁴⁴⁴ http://www.gemalto.com/public_sector/transport.html

M-ticketing technology is still young and goes hand in hand with the development of electronic payment systems via mobile phones.

- Policy Framework and current initiatives

EU framework for electronic and mobile ticketing is mainly based on the following:

- **Payment Services Directive (PSD)**⁴⁴⁵ aims to create a true European market for payments while improving national businesses at the same time, offering consumers more and cheaper services
- **E-Commerce Directive (2000/31/EC)**⁴⁴⁶ which sets up an Internal Market framework for electronic commerce, which provides legal certainty for business and consumers alike. It establishes harmonised rules on issues such as the transparency and information requirements for online service providers, commercial communications, electronic contracts and limitations of liability of intermediary service providers
- **e-Europe Smart card initiative**⁴⁴⁷ in the context of the e-Europe action plan (2002/2005 and now i2010) which led to the establishment of a smart card charter recognised by the European Council and to R&D projects, e.g. under FP5 (Fifth Framework Program)⁴⁴⁸

The European Commission is also assisting MS in the implementation of e-ticketing services: for example, the EC authorised a State aid measure by Germany aimed at supporting the development of an electronic fare management system for public transport, the so-called "e-ticketing system". The approved State aid amounts to approximately € 9.75 million and will be granted between 2007 and 2009⁴⁴⁹.

In the field of smart cards, often used in the public transportation sector, many associations and public institutions such as the Public Road Administration in Norway, RKF in Sweden and Denmark, ITSO in the UK and the Verband Deutscher Verkehrsunternehmen (VDV) in Germany have put significant efforts into the standardisation of interoperable fare collection systems and therefore, achieved substantial progress. Besides these initiatives, new standards evolve and try to provide transport operators and authorities with a conceptual framework for interoperability on a European as well as on an International level:

⁴⁴⁵ http://ec.europa.eu/internal_market/payments/framework/index_en.htm

⁴⁴⁶ http://ec.europa.eu/internal_market/e-commerce/directive_en.htm

⁴⁴⁷ <http://eeurope-smartcards.org>

⁴⁴⁸

http://cordis.europa.eu/data/PROJ_FP5/ACTIONeqDndSESSIONeq112422005919ndDOCeq526ndTBLeqEN_PROJ.htm

⁴⁴⁹

<http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/673&format=HTML&aged=0&language=EN&guiLanguage=en>

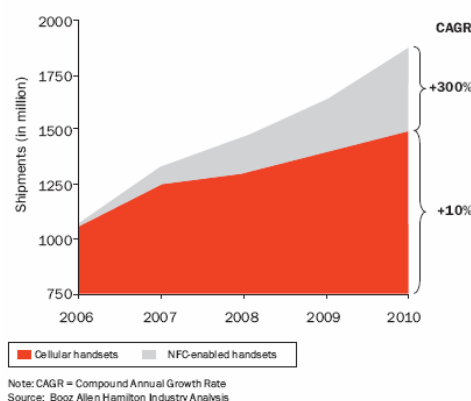
- EN15320 - Interoperable Public Transport Application (IOPTA)
- ISO 24014-1 - Interoperable Fare Management System (IFMS)

- Trends

E-ticketing seems to be already widespread in Europe and not subject to further significantly increase in the future.

However, **m-ticketing** is still at an early stage of its development. Mobile ticketing based on NFC technology is set to allow for the take-off and breakthrough of electronic ticketing in public transport by being both affordable and value adding. It also stresses that the key success factor for bringing this new technology to life is a partnership between the three industries of public transport, telecommunications and financial services, rather than between single enterprises in these sectors. M-ticketing based on NFC technology built in handsets is believed to have a great potential for deployment in the future, with a projected increase of 300% year over year up to 400-440 million NFC-enabled handset shipments in 2010.

Figure 63: Market forecast for NFC-enabled devices 2006-2010⁴⁵⁰



M-ticketing technology goes hand in hand with the development of electronic payment systems via mobile phones. Forrester Research⁴⁵¹ estimates that mobile payments will amount to €26 billion in 2005 and gross profit to €1.3 billion. Mobile payments are becoming a field of priority, and an increasing number of solutions are being developed, tested, piloted or rolled-out⁴⁵². Business drivers for mobile commerce are different for each player: telecommunication operators have invested high amounts of money on license purchasing⁴⁵³ and need to recover investments through the increase

⁴⁵⁰ Booz Allen & Hamilton. Next Generation e-ticketing, March 2007.
http://www.boozallen.com/media/file/Next_Generation_eTicketing.pdf

⁴⁵¹ Forrester Research, May 2001 Report "Mobile Payment's Slow Start"

⁴⁵² ePSO Database on e-Payments. (ePSO: electronic Payment Systems Observatory at the DG Joint Research Centre - Institute for Prospective Technological Studies. <http://epso.jrc.es/paysys.html>)

⁴⁵³ According to UMTS forum Report No. 13, European mobile operators have already invested more than \$100 billion in acquisition of licences for 3G spectrum <http://www.umts-forum.org/reports.html>

of the voice and data traffic; banks seek to use the mobile device as a new delivery channel for financial services and to maintain their role as payment service providers; new business opportunities appear also for mobile device manufacturers, technology, application, service and content providers.

A few indicative examples of commercial efforts in mobile payment solutions in Europe can be given (not all of them are in operation today):

- Germany: PayBox (www.paybox.net), StreetCash (www.streetcash.de), Firstgate Click&Buy (www.firstgate.de)
- Spain: Mobipay (www.mobipay.com), VISA Movíl,
- Finland: Electronic Mobile Payment Services (EMPS)
- The Netherlands: MoxMo (www.moxmo.com)
- Denmark: BeamTrust (www.beamtrust.com), Orange/Mobilix mobile payment (www.orangemobilbetaling.dk), Metax (www.metax.dk)
- France: “Paiement CB sur mobile”
- Sweden: Telia Payit, Mint (www.mint.nu)
- Norway: MobilHandel (www.mobilhandel.no)
- Italy: Easybuy by i-Tim (www.tim.it), MobilMat (www.mobilmat.it)
- Czech Republic: Oskar
- Ireland: mpark (www.mpark.ie)
- United Kingdom: M-till (www.m-till.com)

Some are pretty general while others are scenario-specific such as mobile ticketing (e.g. mpark in Ireland). In the specific field of mobile ticketing, the European situation seems to be at a very early stage, and is still under development. In 2007, a German leading ICT company announced the deployment of mobile phone scanners at concerts around Europe. Mobile scanners are currently installed at various concerts in Germany, the PinkPop Festival in the Netherlands, the Christina Stürmer's concert in Austria, and the Dutch singer Guus Meeuwis concert, and in the future, mobile ticketing could become a standard ticketing method. According to a study, by 2010, 87 million European mobile users (15% of total) will be using their mobile devices for mobile

ticketing purposes⁴⁵⁴. The French operator France Telecom is also experimenting contact less services by mobile phone to facilitate travel for passengers of SNCF (French National Railway Company), Keolis (bus) and Effia (inter-modal operator), the latter two being subsidiaries of SNCF in the region surrounding Rennes (November 2007 announcement).

- Analysis of case studies and assessment of the improvement potential at a micro level

As no case study was available to quantify the effects of e-ticketing/mobile-ticketing, rough assumptions were made in order to provide an estimate of the potential effects of such practices in terms of energy efficiency.

Base case: e-ticketing / m-ticketing

Context:

E-ticketing and m-ticketing enable the reduction of paper consumption and of transportation needs.

Most airlines propose e-tickets, and more and more railway companies are joining in. However, no case studies were found to assess the potential benefit of e-ticketing and instead assumptions on the emissions of CO₂ and energy consumption of paper production were used to provide an overview of the potential benefits of e-ticketing in three selected areas:

- Air travel
- Train travel
- Movies
- Public transportation

These four areas were selected as they seem to be the ones which are the more incline to develop e-ticketing and m-ticketing applications. For example, concert halls and theatres are often run by small organizations which are less likely to adopt m-ticketing.

Methodology and assumptions:

For each area, a traditional scenario where a paper based ticket is bought at a ticketing booth is compared to an electronic scenario where the customer pays a digital ticket and does not require printing any document.

Printing is unnecessary when purchasing m-tickets, or when purchasing online tickets with the possibility of simply presenting an identity card as it is already the case for air

⁴⁵⁴ Juniper research. Mobile Commerce Strategies Ticketing, Retail, Payment & Security, 2005-2010 (Second Edition). 2006

travel. It would also be the case if mobile ticketing was applicable for train travels⁴⁵⁵ and for movies.

The consumption of paper is the main parameter investigated here (avoided paper production). The impacts due to transport (to the ticket booth) are not taken into account, nor the impacts due to the use of ICT equipment, either computer and internet infrastructure or mobile telephone and cell phone infrastructure.

- As for the e-government analysis, the impacts of paper production are evaluated in terms of **primary energy used during the production process**. A factor of 31 MJ /kg of paper produced was taken as reference, based on the Ecoinvent 1.3 inventory for the European situation⁴⁵⁶, and considering the European situation for the end-of-life of paper (see explanation in section 3.1.1.3).
- The following weights are assumed for the different types of traditional tickets (Table 150):

Table 150: Assumptions related to the weight of the paper-based tickets

Traditional ticket (paper)	One ticket weight (g)
Air travel	6
Train travel	3
Movie	1
Public transportation	1

Results:

- The results are provided for the replacement of one million tickets of each kind by electronic or mobile tickets in Table 151. For converting the energy savings into CO₂ eq. we used the carbon emission factor used by the EuP EcoReport tool which the official life cycle analysis tool used developed in the context of the EuP Directive 32/2005/EC (0.4582 kg CO₂ eq. /kWh - assumed to remain constant throughout the period under review (2005-2020)).

Table 151: Savings when using e-ticketing/m-ticketing - net savings in CO₂ eq.

Application (one million tickets)	Savings in primary energy consumption (avoided paper production) MJ	Savings in CO ₂ emissions (avoided paper production) t	Savings in electricity due to avoided end-of-life (kWh) electricity	Savings in electricity due to avoided end-of-life (MJ) Primary energy	Savings in t CO ₂ eq. due to avoided paper end-of-life phase (European scenario)	Tons CO ₂ eq. Total Net savings
e-ticket air travel	186,000	9.9	-347	-3,641	0.3	10.2

⁴⁵⁵ In France, France Telecom (telecommunication operator) and SNCF (National Railway company) are exploring this possibility

⁴⁵⁶ Ecoinvent 1.3, Paper, recycling, with deinking, at plant RER S

m-ticket train	93,000	5.0	-173	-1,821	0.1	5.1
m-ticket movie	31,000	1.7	-57.8	-607	0.0	1.7
Public Transportation	31,000	1.7	-57.8	-607	0.0	1.7

Table 152: Savings when using e-ticketing/m-ticketing - net savings in toe

Application (one million tickets)	Net savings Primary energy (avoided production and end-of-life) (MJ)	Net savings in primary energy consumption (avoided production and end-of-life) toe	Equivalent electricity savings based on the primary energy net savings (MWh) ⁴⁵⁷	Equivalent electricity savings based on the primary energy savings (toe ⁴⁵⁸)
e-ticket air travel	182,359	4	17	1.5
m-ticket train	91,179	2	9	0.7
m-ticket movie	30,393	0.7	2.9	0.2
Public Transportation	30,393	0.7	2.9	0.2

Discussion of the results and conclusions:

This simplified analysis only provides an indication of the potential electricity savings that could be achieved through e-ticket/mobile ticketing and avoided paper production. The most significant potential seems to rely in mobile ticketing for which the user does not need to print any document. However, this technology requires the use of ICT equipment (chips, barcode readers, etc.) which might slightly reduce the announced savings.

Also, in the case of e-tickets and m-tickets for travelling purposes, rebound effects should be closely looked at. The digital format allows reducing the administrative costs and overall cost of a ticket enabling more attractive prices for customers. Such practice could eventually increase traffic.

- Recommendations and evaluation of the option
- BAU and Eco-scenario impact analysis at EU-level

In this section, the approach is to extrapolate the savings related to the substitution of one million paper-based tickets by an m-ticket or an e-ticket at the scale of Europe, considering different scenario for the roll out of e-ticketing and m-ticketing in different areas (rail transport, and movies).

⁴⁵⁷ Calculated using the EcoReport factor : 1MWh electricity = 10,500 MJ primary energy

⁴⁵⁸ IEA conversion factor 1 toe = 11.63 MJ

The public transportation sector was not investigated further because of unavailable estimates of the total number of passenger trips via urban mass transit in Europe until 2020. The air transport area was not further investigated as it is assumed that it reaches saturation in terms of e-ticket penetration (96.5 %) in the baseline scenario (i.e. no improvement potential).

For the rail transport and movie sectors, the scenario are very rough estimates as no statistics until 2020 were not available to assess the total sale of tickets (both paper-based and electronic) and assumptions were necessary to estimate the take up of electronic vs. traditional ticketing (Table 153).

A baseline scenario was established to serve as the basis for calculating the improvement potential for various BAU scenarios and Eco-scenario.

Table 153: Assumptions for potential improvement scenarios (ICT based ticketing 2020)

	2020 Share of electronic tickets among total ticket sold	Comment
Air transport		
Baseline	96.5%	IATA target in 2008 (May), we assume the market for e-ticket is saturated
Train tickets electronic or mobile		
Baseline	5%	No take-up of e-ticketing in the rail sector was assumed compared to the 2005 situation
BAU scenario (average)	10%	Various scenarios were assumed as no data was available to project the penetration of ICT based ticketing in the rail transportation sector more precisely. It can be assumed that e-ticketing will see a growing success in the rail sector as it can provide cost savings in-line with that of airlines that use e-ticketing ⁴⁵⁹ which will encourage rail provider to adopt e-ticketing.
BAU scenario (High)	20%	
Eco-scenario (average)	40%	
Eco-scenario (High)	60%	
Movie tickets		
Baseline	5%	No take-up of e-ticketing in the rail sector was assumed compared to the 2005 situation
BAU scenario (average)	5%	No take-up of e-ticketing in the rail sector was assumed compared to the 2005 situation
BAU scenario (High)	10%	We assumed various scenarios as no data was available to project the penetration of ICT based ticketing in the movie sector. However, as tickets for movies are often bought "last minute" (e.g. at the movie theatre) is it unlikely that the take-up of ICT based tickets will be considerable
Eco-scenario (average)	15%	
Eco-scenario (High)	20%	

On the basis of the assumptions presented in Table 153 and based on the basic data presented in Table 154, the different scenarios for ICT based ticketing were calculated in the rail transportation sector and in the movie sector.

⁴⁵⁹ IATA estimates that \$9US dollars are saved every time an e-ticket is issued rather than a paper ticket

The results are presented in Table 154 and based on the results presented in Table 151.

They show that implementing ICT based ticketing in the rail sector could save between 3,471 MWh and 38,178 MWh in energy consumption (avoided paper production and end-of-life) equivalent to 298 and 3,283 toe, and to 2,030 and 22,334 t CO₂ eq. respectively compared to the baseline 2020 situation. In the movie sector, results shows that, depending on the scenario, up to 391 MWh (equivalent to 34 toe or 229 t CO₂ eq.) could be saved through reduced paper production compared to a baseline 2020 situation.

The results provide a very wide range of savings, depending on the scenario considered. However, they still provide an idea of the magnitude of the energy saving potential when implementing ICT-based ticketing in the rail sector or the movie sector. The uncertainty of the results is linked to the lack of available statistics on the uptake of ICT based ticketing in Europe.

Table 154: Baseline, BAU and Eco-scenarios for ICT based ticketing and estimated magnitudes of the savings

	Basic data				Assumptions		Calculations Improvement potential			
	Total sales 2005	Share ICT based tickets 2005	Total ICT based tickets 2005	Total sales 2020	Share ICT based tickets 2020	Total e-tickets 2020	Improvement potential in terms of paper tickets avoided compared to baseline	Net savings in equivalent electricity due to avoided paper production compared to baseline (MWh)	Net savings in equivalent electricity due to avoided paper production compared to baseline (toe)	t CO2 eq. Total Net savings compared to baseline
Air transport										
Baseline	N/A	50%	N/A	N/A	96.50%	N/A	0.0	0.0	0.0	0.0
Rail transport (train tickets electronic or mobile)										
Baseline	7,993,533,000 ⁴⁶⁰	5%	399,676,650	7,993,533,000 ⁴⁶¹	5%	399,676,650.0	0.0	0.0	0.00	0.00
BAU scenario (average)					10%	799,353,300.0	399,676,650.0	3,471	298	2030
BAU scenario (High)					20%	1,598,706,600.0	1,199,029,950.0	10,412	895	6091
Eco scenario (average)					40%	3,197,413,200.0	2,797,736,550.0	24,295	2,089	14213
Eco scenario (High)					60%	4,796,119,800.0	4,396,443,150.0	38,178	3,283	22334
Movie tickets										
Baseline	900,000,000 ⁴⁶²	5%	45,000,000	900,000,000 ⁴⁶¹	5%	45,000,000.0	0.0	0.0	0.00	0.00
BAU scenario (average)					5%	45,000,000.0	0.0	0	0	0
BAU scenario (High)					10%	90,000,000.0	45,000,000.0	130	11	76
Eco scenario (average)					15%	135,000,000.0	90,000,000.0	261	22	152
Eco scenario (High)					20%	180,000,000.0	135,000,000.0	391	34	229
Public transportation tickets										
Baseline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BAU scenario					N/A	N/A	N/A	N/A	N/A	N/A
Eco scenario					N/A	N/A	N/A	N/A	N/A	N/A

⁴⁶⁰ Assumed no change compared to 2006 – 2006 data from EUROSTAT (Total rail passenger EU 27)

⁴⁶¹ Assumed no change compared to 2005

⁴⁶² Estimation from the European Audiovisual Observatory http://www.obs.coe.int/about/oea/pr/berlin_2006.html

Table 155 sums the savings related to the implementation of ICT based ticketing in both the rail transportation sector and the movie sector. Savings in electricity consumption between 3,471 MWh (298 toe or 2030 t CO₂ eq.) and 38,568 MWh (3,316 toe or 22,553 t CO₂ eq.) were calculated depending on the scenario considered.

A reasonable scenario (average) would be to conclude that ICT based ticketing could provide 19,284 MWh energy savings, equivalent to 1,688 toe (11,282 t CO₂ eq.) in the rail and movie sectors. Further savings would be possible within the public transportation sector which could represent a mass market application of m-ticketing.

Table 155: Estimated magnitudes of energy savings via ICT based ticketing in rail and movie sector (avoided paper production)

Total substituting train tickets and movie tickets	Net savings in equivalent electricity due to avoided paper production compared to baseline (MWh)	Net savings in equivalent electricity due to avoided paper production compared to baseline (toe)	t CO ₂ eq. Total Net savings compared to baseline
BAU scenario (average)	3,471	298	2,030
BAU scenario (High)	10,542	906	6,168
Eco scenario (average)	24,555	2,111	14,365
Eco scenario (High)	38,568	3,316	22,563
Average scenario	19,284	1,658	11,282

- Recommendations

Since the 1990s, key players in the European public transportation industry have sought to replace paper ticketing with electronic “e-ticketing” to improve customer convenience and reduce expenses for transport agencies. Smart-card based e-ticketing however implies high initial investments, ongoing operating costs, and complex infrastructure requirements which could discourage the use of popular chip-based “smart cards”. M-ticketing based on NFC-technology seems to be the “next generation” e-ticketing, enabling both economic and environmental benefits. A recommendation would be **to encourage a cooperative venture between Europe’s public transportation, telecommunications, and finance industries** which can improve customer service and reduce initial investments by 70 to 80% compared to setting up a smart-card based infrastructure⁴⁶³.

- Rebound effects (large scale)

⁴⁶³ Booz Allen Hamilton. *Next Generation e-ticketing* 2007
http://www.boozallen.co.uk/media/file/Next_Gen_eTicketing_final.pdf

Depending on the sector of application (e.g. air transportation, rail transportation, movies) the rebound effects will differ.

In the airline industry, it has been already observed that lowering the cost of tickets (either through e-ticketing or other strategies such as minimising ground handling costs etc.) increases the airline traffic⁴⁶⁴. A study by ELFAA (European Low Fares Airlines Association) shows that when a low cost company enters the airline market, it creates quite a transformation: out of its total market, 59% is newly generated demand while 37% comes from the existing airline market. The same study shows that out of the newly generated demand, 71% would not have previously travelled, 15% would have travelled by car while only 6% shift is from the railways.

However, in the mass transit sector and in the rail transportation sector, increased traffic seems to be less problematic as it would rather benefit the overall transport sector (rail and public transportation being more environmentally friendly than travelling by air, car or using a personal car).

3.1.4.2 E-Banking and e-invoicing

■ Description of the e-service and related ICT applications

The functions provided by online banking (e-banking) have evolved from allowing customers to consult their accounts to providing a full range of banking services. In the most developed applications, the Internet can replace almost the whole range of services available at branches or by phone. In addition to offering nearly all "branch-based" services, the technology allows banks to offer new added value services such as e-mail alerts, electronic commerce, real-time share trading and 3rd party services such as the management of utility bills and tax payments.

The most frequently used services are those that provide financial information (account information, loan and insurance rates, investment reports and advice). Other heavily used services are simple transactions such as paying bills and transferring money. Finally, there seems to be an evolution in usage patterns from more consultative functions towards more transactional ones, which seems to indicate users' trust in Internet banking is increasing over time. However, the number of users of on-line trading functions and investment research and advice is expected to remain limited⁴⁶⁵.

⁴⁶⁴ 19 % year to year growth in passenger carried according to 2007 statistics from ELFAA (European Low Fares Airlines Association)

⁴⁶⁵ The IPTS Report - Issue 77 - September 2003

Electronic invoicing (e-invoicing) is the issuing of invoices by email directly to the customer.

The European commission defines e-invoices as: “the electronic transfer of invoicing (billing and payment) information between business partners.”

The European e-business watch special report⁴⁶⁶ provides the following definition of e-invoices:

“Electronic invoicing is a computer-mediated transaction between a seller/biller (invoicing entity) and a buyer/payer (receiving entity), which replaces traditional paper-based invoicing processes. In e-invoicing, the invoice is electronically generated and sent by the biller and electronically received, processed and archived by the payer. In practice, e-invoicing typically goes hand in hand with making payments electronically”

Electronic invoices can be designed for B2B or for B2C transactions. B2B e-invoicing systems are usually designed as a two-way process, i.e. both sides can issue and/or receive invoices. B2C systems are predominantly designed in a way that only consumers can receive (and pay) invoices. Transactions between businesses and the public sector are structurally similar to B2B processes.

E-invoicing can either be accomplished in a web-based environment (e.g. B2C e-invoices), or processes can be integrated with the ERP system of a company (B2B e-invoicing).

- Analysis of the policy framework at EU level, business initiatives, analysis of the e-service status and trends in the EU
- Status
- **Internet banking** is one of the most widely used e-commerce applications, in 2002, it accounted for between 5% and 10% of the total volume of retail banking transactions in Europe⁴⁶⁷. In 2005, it is estimated that between 10 and 15 % of the total volume of retail banking transactions in Europe are made online⁴⁶⁸.

⁴⁶⁶E-business watch special report. *ICT Security, e-Invoicing and e-Payment Activities in European Enterprises*. 2005
http://www.empirica.biz/ebusiness_watch_V/studies/special_topics/2005/documents/TR_2005_Payments_IV.pdf

⁴⁶⁷ UNCTAD, United nations Conference on Trade and Development, *E-commerce and development Report*, 2002.

⁴⁶⁸ Estimation based on the basis that in 2002 according to Datamonitor (see footnote 470) there are 39 million online banking customers in Europe, and that internet banking accounted for 5-10 % of total banking transactions; and that in 2005 there were 69 million online banking customers in Europe.

- It is much more significant than business-to-consumer e-commerce. In the business sector, for the year 2005 it is estimated that about 70 % of European enterprises subscribed to online banking services⁴⁶⁹.

The number of consumers banking online in Europe (Belgium, France, Germany, Italy, Spain, the Netherlands, the UK and the Nordic region) has grown from 39 millions in 2002 to 63 millions in 2005⁴⁷⁰. However, traditional channels (e.g. physical branches, phone, ATMs, PC-based dial-up access) remain widely used by customers, and the internet's potential still remains unfulfilled by both providers and end-users.

While banks have been relatively successful in signing up customers to online banking via various marketing approaches, a significant proportion of these customers do not actively use the service. Possible identified barriers to further spread of online banking use could be fraud which represents a major issue affecting the online channel. Also, the analysis of case studies (Sweden) as well as reports of a number of banks, implies the potential importance of PC and Internet access at home (vs. work, PIAP (Public Internet Access Programs) and University) for the adoption of Internet banking.

Germany has the highest number of customers banking online, with 15.4 million, followed by the UK with 12.1 million, in 2005. The Nordics appear to be at the forefront of the other European countries in terms of Internet banking penetration. Estimates indicate that in 2003 and 2006 about 40% of banking customers in the Nordic region bank online⁴⁷¹ compared to about 10% in Germany, France, and Italy in 2002 (Figure 64).

⁴⁶⁹ i2010 mid-term review

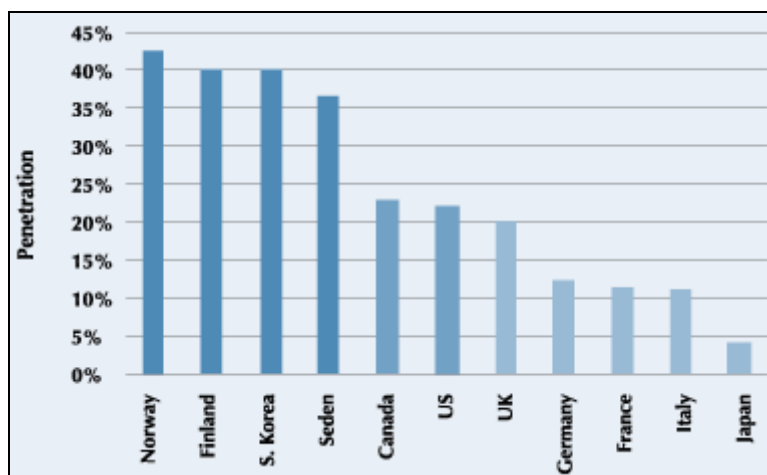
http://ec.europa.eu/information_society/eeurope/i2010/docs/annual_report/2008/sec_2008_470_Vol_1.pdf

⁴⁷⁰ Datamonitor. *Online Banking Strategies in Europe*. 2006

http://clanglois.blogs.com/InternetBanking/Datamonitor-Online_Banking_Strategies_in_Europe_2006.pdf

⁴⁷¹ ibid

Figure 64: E-banking penetration rates in 2002⁴⁷²



There are potential environmental and financial benefits to be delivered by online banking: reduction of transportation needs to the bank, reduction of paper-based documents, and reduction of office space needs, leading to reduction of costs per internet transfer compared to traditional ones.

However, these potential financial benefits might be offset by (additional) processes and requirements, such as the need for hard- and software or the potential increase in private mobility due to the time savings (rebound effect).

Concerning e-invoicing, a European survey indicates that about 5% of all firms surveyed in 2005 have reported using ICT systems for electronically invoicing their customers. Similarly, about 5% use systems for billing invoices from suppliers electronically. Activity clearly increases in both cases by firm size. More than 10% of medium-sized and 15-20% of large companies invoiced customers electronically

Differences are not very pronounced by sector of activity, with the possible exceptions of the IT services sector which is a forerunner in electronic billing and invoicing and it appears that e-invoicing might not yet be widely diffused.

⁴⁷² The IPTS Report - Issue 77 - September 2003
<http://www.jrc.es/home/report/english/articles/vol77/ICT2E776.htm>

Table 156: E-invoicing in Europe, readiness, potential and current state of adoption in 10 sectors

Sector		E-Invoicing readiness		E-Invoicing potential	Current state of adoption	
	Criteria	ERP & CRM installed base	E-commerce activity	Type of business activity, customer structure	Relative to other sectors	In % of firms (estimate)
Food and beverages		★★	★	★★(★)	●	~ 2-5%
Textile industry		★★	★	★★(★)	●●	~ 4-8%
Publishing and printing		★★	★★★	★★★(★)	●●	~ 3-6%
Pharmaceutical industry		★★★★	★★	★★★	●●	~ 5-8%
Machinery and equipment		★★★	★(★)**	★★★	●●	~ 3-6%
Automotive industry		★★★	★(★)**	★★★★	●●	~ 4-8%
Aerospace industry		★★★	★(★)**	★★★★	●●●	~ 8-12%
Construction		★	★	★★(★)	●	~ 2-5%
Tourism		★	★★★★	★★(★)*	●●●	~ 5-10%
IT services		★★★★	★★★★	★★★★	●●●●	~ 10-15%

★ = low; ★★ = medium; ★★★ = high; ★★★★ = high, also in SMEs

Note: "low" / "high" is defined in relation to the average of the sectors monitored.

ERP = Enterprise Resources Planning; CRM = Customer Relationship Management

* In tourism, the potential varies considerably by segment. While opportunities may be promising for airlines, tour operators and hotels, e-invoicing will be less relevant for example for bars or restaurants.

** Mainly e-procurement activity by larger companies, comparatively few companies selling online.

A second survey⁴⁷³ undertaken in 2006 indicates that when looking only at those companies that actually use e-invoicing, the average share of e-invoices (measured as a percentage of a company's total invoices sent or received) is about 15-20%. Large firms usually have a higher share of electronically sent invoices than for receiving. In very small companies it is the other way around.

Compared to paper invoices, e-invoices can obviously reduce paper consumption. Moreover, e-invoices are thought to offer significant advantages for enterprises' competitiveness. Their electronic format allows them to be easily processed and accessible, quickly sent, and stored centrally at very low cost. Conservative estimates⁴⁷⁴ expect potential cost savings of up to € 243 billion across Europe in the business to business field alone. E-invoicing also has the potential to reduce paper-based bills.

- Analysis of the policy framework and business initiatives

The European policy framework for e-banking/e-invoicing is supported mainly by the following:

- The Electronic Commerce Directive 2001/31/EC
- The EU Financial Services Action Plan designed to open up a single market for financial services in the EU. Begun in 1999, it comprises 42 measures designed to

⁴⁷³E-business watch. *The European E-business Report*. 2005

http://www.ebusiness-watch.org/key_reports/documents/EBR05.pdf

⁴⁷⁴ The EACT (European Associations of Corporate Treasurers) project CAST (Corporate Action on Standards).

harmonise the member states' rules on securities, banking, insurance, mortgages, pensions and all other forms of financial transaction.

- Trends

The development of the online channel is expected to continue to be a strategic focus for European banks and investments in the online channel appear to increase at a sustained rate. For example, online banking IT spends for the UK is expected to grow 17.5% between 2006 and 2009, from about €410 million to €480 million⁴⁷⁵.

The trends describing the development of online banking and e-invoice are very similar to the general trend in e-commerce described later in section 3.1.5.2. However, a European study reported that e-banking is the most frequently used applications of digital services today⁴⁷⁶.

As for any e-commerce application, limited PC ownership, cost of Internet access and cost of PCs are inhibiting market development of online banking and e-invoice.

- Analysis of case studies and assessment of the improvement potential at a micro level

- Case study: online banking

E-banking is documented in a very detailed document published by the European Commission⁴⁷⁷. However, this study uses the MIPS methodology (Material Input per Service Unit) and expresses the results of the environmental impacts analysis in terms of kg abiotic raw materials/ kg biotic raw materials and water consumption and could not be translated into more common indicators. According to the study and when "translating" the calculation results into a more accessible language, the bill payments material intensity can be compared with another product or service. The MIPS concept allows comparisons between seemingly incomparable issues, since the final results per service unit are expressed in "kg material intensity". The example chosen to compare the bank account statement with is the production of aluminium beverage cans. A total material requirement of 2.76 kg per traditional bank account statement is equal to that required to produce ten aluminium cans. Online bank account statement, with slightly more than 1 kg still equals the production of four cans (taking into account modifications in the whole banking infrastructure e.g. reduction in floor space and building energy requirements, reduction in transport, increase in ICT equipment).

⁴⁷⁵ \$600 million to \$705 million

⁴⁷⁶ Digital Europe. The environmental and social impacts of e-banking. 2003.
<http://www.forumforthefuture.org.uk/files/DigitaleuropeOnlinebankingcasestudy.pdf>

⁴⁷⁷ Digital Europe. The environmental and social impacts of e-banking. 2003.
<http://www.forumforthefuture.org.uk/files/DigitaleuropeOnlinebankingcasestudy.pdf>

It seems that e-banking could provide significant energy efficiency improvements and some rough calculations were made in order to provide an overview of what could be achieved through e-banking.

Case study: E-banking

Context:

As no case study was available to quantify the effects of e-banking, rough assumptions were made in order to provide an estimate of the potential effects of e-banking in terms of energy efficiency.

Methodology and assumptions:

A simplified analysis can be performed, considering the following scenarios to compare:

- - Traditional service: the customer is issued a paper account statement on a **monthly** basis. Each account statement is composed of **three A4 paper sheets** (80g/m², i.e. about 5 g per page) and is sent via post.
- - E-banking: the customer checks his account statement online, without printing the document and stays 5 minutes online via a desktop computer, on a monthly basis.

In this simplified analysis the transports of paper documents were not taken into account (postal services) nor were the impacts of the internet infrastructure.

This simplified scenario does not include further online banking services such as the possibility of making money transfer through the internet.

Data used for paper production and end-of-life were the same used for the e-ticket case study.

Results:

According to these assumptions, 50 million customers e-banking across Europe avoid **9000 tons** of paper per year which is equivalent to savings of **2,240 toe** (equivalent electricity savings) and **15,241 tons CO₂ eq.** (using the same assumptions related to paper production electricity use as for e-ticketing).

Discussion of the results and conclusion:

A simplified analysis shows that online banking can allow significant energy savings through reduced paper production if the end-user does not print. However, these calculations do not take into account the transportation (postal services) nor the internet infrastructure or computer use and these results should only be seen as a good order of magnitude of the savings related to the reduction of paper consumption.

These results could also be extrapolated to assess the impacts of an e-mail vs. a 1 page letter.

The Digital Europe case study, and our rough calculation conclude that online banking shows signs of being beneficial compared to traditional banking. However, this conclusion can only be sustained, as long as online banking substitutes traditional banking in such a way that the material and resource intensity in traditional banking is reduced. However, the Digital Europe case study reports that current practice indicates that online banking is an additional banking channel (to provide maximum customer choice), and not a substitute leading to any relevant changes in terms of the material intensity of the traditional channel and this should be taken into account when developing scenarios at the EU-scale. According to their case study, they report that by assuming that the building infrastructure as well as the electricity, water and gas consumption will not change considerably with an increasing online banking share (complementary channel of service and no substitution), e-banking will actually increase the material intensity in the banking sector. The reason for this is not only that it is an additional consumption but also, that by disregarding the infrastructure-related aspects of the calculation (building, electricity, gas, water), the traditional banking specific consumption (credit slip + transport) is only half as material intense as the online specific one (bank and consumers IT infrastructure + related power consumption). This outcome changes of course, if the multi-channel strategy is not a transitional phenomenon, but a long-term strategy. If banks are going to reduce their building infrastructure in the long run, either by closing branches or reducing branch sizes, online then the online scenario is less resource intensive than the traditional scenario.

- Case studies: e-invoicing

Case study: Deutsche Telekom⁴⁷⁸

Online billing was investigated at Deutsche Telekom. The main target of the study was to encourage the use of ICT technology, and to look at potential savings of natural resources (paper) and potential cost savings.

The calculation was based on the estimate that 1 million customers/year is equivalent to 206 tonnes of recycled paper for their invoices (including envelopes). For the year 2004 in Germany among Deutsche Telekom was 2.8 million customers, which corresponded to about 576.8 tonnes of paper. Assuming that all customers switch to online billing, this would therefore save 576.8 tonnes of paper. Based on the data used for paper production and end-of-life for the e-ticket case study, they calculated that this corresponds to about 1.6 MWh energy savings (836.36 tonnes of CO₂ eq. using German conversion factor of 0.419 kg/kWh) through avoided paper production and 836.4 tonnes CO₂ eq. through avoided paper incineration during end-of-life.

Case study: E-invoicing in Denmark⁴⁷⁹

⁴⁷⁸ETNO. *Greenhouse Gas Effect of Information and. Communication Technologies*
http://www.etno.be/Portals/34/events/VIS2005/projectdocu_Final.pdf

As of February 1st 2005, all public institutions were required only to accept invoices from suppliers in electronic format. Thus, all public sector entities have been required to convert all systems and administrative processes from physical to digital handling of invoices, credit notes and other transactions. This affected about 15 million invoices in the entire public sector from ministries to nursery schools.

Results of such operation are summarised below:

- Estimated benefits are 120-150 million per year (¼ from national government, ¾ from local government)
- Costs of implementation are 1/10 of the benefits
- Savings are earmarked for public treasury
- Reduced workload on both sides by, at the same time, more qualitative work (e.g. elimination of re-keying of data)
- Faster processing of service
- eInvoicing helps companies prepare themselves for other public digitalization initiatives and among companies

However, no energy/material savings were quantified.

■ Recommendations and evaluation of the option

● BAU and Eco-scenario impact analysis at EU-level

According to a previous study⁴⁸⁰, e-banking is developing fast but is not destroying the traditional banking business model nor promoting the entry of newcomers from outside the banking industry. E-banking is more a complementary tool to traditional banking and internet-only banks have been less profitable⁴⁸¹. The prevailing vision for the success of e-banking is that it should be integrated within the existing banking structure due to the importance of public trust in banks and to the desire of customers to have a physical interface. Internet banking is therefore more projected to be another distribution channel as a complement to physical branches, phone banking and ATM networks.

⁴⁷⁹ Ralf Cimander et al. . *eInvoicing in Denmark* 2007
<http://www.epractice.eu/files/upload/gpc/document/1967-1170249373.pdf>

⁴⁸⁰ Mu Yibin (The World Bank, Harvard University). *E-Banking: Status, Trends, Challenges and Policy Implications* (November 2003)

⁴⁸¹ They generate lower business volumes and the savings generated through dematerialisation appear to be offset by other types of non-interest expenditure such as marketing to attract new customers (in De Young. *The financial progress of pure-play internet banks*. 2003)
<http://www.bis.org/publ/bppdf/bispap07h.pdf>

This view is also supported by the Digital Europe study, which foresees that the multi-channel strategies will prevail in the banking sector and that e-banking will actually lead to an increase in the banking sector's overall material intensity.

Based on these prevailing future views on the development of e-banking, and in the perspective of quantifying energy efficiency savings, it was therefore decided not to develop scenarios for online banking.

For online billing, as invoices could be of very different types, no future scenario was developed either.

- Recommendations

As e-banking will continue to grow, the main environmental effects that arise are related to the energy and infrastructure requirements. Therefore it can be concluded that the established policy instruments such as voluntary agreements, incentives and taxes are also required in the digital economy. Internalisation of external effects still seems to be one of the best measures to reduce the environmental impacts. In addition incentives should be given to speed up the transitional process towards e-banking. In that respect, there is a need for banking customers to be familiarised with the internet technology and the security⁴⁸² of internet transactions needs to be improved.

- Other environmental impacts (large scale)

No significant other environmental impacts, aside from potential reduction in building infrastructure, were identified.

3.1.4.3 Digital Music

- Description of digital music and related ICT applications

Digital music (e-music) refers to music files in digital format which are transferred into a downloadable and playable music format and stored on a server. From that server, the customer can download the file. Once the music files are downloaded via the internet, the user can decide to either store the music on the hard disk of the PC or some other sort of storage device (e.g. external hard drive), either to store on blank CDs (CD burning).

- Analysis of the policy framework at EU level, business initiatives, analysis of the e-service status and trends in the EU

⁴⁸² According to a previous survey for the year 2005 by Deutsche Bank, The fear of a lack of security is a higher hurdle to those internet users who do not use online banking than missing monetary incentives or insufficient comfort or functionality
http://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000185427.pdf

- Status

In 2004 in Europe, 14 million single tracks were downloaded (legally, i.e. paid for) on the internet (excluding the mobile phone channel), compared to about 62 million single tracks in 2005 which shows that music is becoming a significant actor of the world's digital economy. In 2005, it is estimated that about 150 legal downloading websites existed, compared to 50 in 2003. According to IFPI (the International Federation of Phonographic Industry), the music digital industry accounted approximately for 15% of the global music industry in 2007. The UK is the fastest-growing online music market in Europe. The UK sales of single tracks downloaded during the year 2007 amounted to 77.6 million, a 47% increase compared to 2006 and a three-fold increase since 2005. Germany is Europe's second largest digital market, with sales in 2005 more than tripling in one year to 21 million downloads. In France, sales of 8 million downloads were reached, compared to just 1.5 million in 2004. In Eastern Europe online music is yet to take off, but the mobile music market is developing quickly, with penetration rates reaching 100%.⁴⁸³

In 2006, however, still less than 5% of European internet users regularly bought music online.

- Policy Framework and current initiatives

- **EU Copyright Directive (EUCD)** (Directive 2001/29/EC) that aims to harmonize the divergent European copyright regimes and to transpose the WIPO-treaties⁴⁸⁴

- **E-Commerce Directive** (Directive 2000/31/EC)⁴⁸⁵ which sets up an Internal Market framework for electronic commerce and provides legal certainty for business and consumers alike. It establishes harmonised rules on issues such as the transparency and information requirements for online service providers, commercial communications, electronic contracts and limitations of liability of intermediary service providers.

- **Directive on the Enforcement of intellectual property rights** (Directive 2004/48/EC). This Directive seeks to harmonise Member States' legislation, thus ensuring an [equivalent level of protection for intellectual property rights across the Member States](#).

- **Directive on a common regulatory framework for electronic communications networks and services (Directive 2002/21/EC)**⁴⁸⁶. This regulatory framework consists of this Directive plus four specific Directives detailed below:

⁴⁸³ IFPI (International Federation of Phonographic Industry) Digital Music Report. 2006

⁴⁸⁴ World Intellectual Property Organization

⁴⁸⁵ http://ec.europa.eu/internal_market/e-commerce/directive_en.htm

⁴⁸⁶ <http://www.euroblind.org/fichiersGB/com200221.htm>

- **Authorisation Directive** (Directive 2002/20/EC)⁴⁸⁷ that aims to harmonise and simplify the rules and conditions for authorising electronic communications networks and services in order to facilitate their provision throughout the Community by introducing a system of general authorisation, instead of individual or class licences.
- **Access Directive** (Directive 2002/19/EC)⁴⁸⁷ which stipulates procedures and principles for imposing pro-competitive obligations regarding access to and interconnection of networks on operators with significant market power. It aims at establishing a regulatory framework for the relationships between suppliers of networks and services that will result in sustainable competition and interoperability of electronic communications services.
- **Universal Service Directive** (Directive 2002/22/EC)⁴⁸⁷ on universal service and users' rights relating to electronic communications networks and services aims at ensuring that operators provide a series of services to all end-users in the whole territory at an affordable price.
- **Directive on Privacy and Electronic Communication** (Directive 2002/58/EC)⁴⁸⁷ concerns the processing of personal data and the protection of privacy in the telecommunications sector. It aims at enforcing that all MS must ensure the confidentiality of communications made over public communications networks and the personal and private data inherent in those communications.

- Trends

A study led by Screen Digest Ltd, CMS Hasche Sigle, and Goldmedia GmbH, Rightscom Ltd for the European Commission in 2006 provides sales estimates and forecasts for the music market from 2003 to 2010 in the European Union.

⁴⁸⁷ http://ec.europa.eu/information_society/policy/ecomm/info_centre/documentation/legislation/index_en.htm

Table 157: Online and physical music revenues in the EU: sales and forecasts from ScreenDigest study

Total EU	2003	2004	2005	2006	2008	2010
'a la carte' 1 download revenue (€m)	2.1	28.8	108.9	270.7	622.2	990.2
Combined buy rate ²	0.2	1.1	3.0	4.8	8.0	10.2
Online music subscriber revenues (€m)		7.9	12.0	14.8	34.1	116.7
EU online music revenues (€m)	2.1	36	120	285	656	1,107
EU total music revenues - online + physical (€m)	9,993	9,384	9,151	8,652	8,307	8,785
Online music revenues as share of total music revenues (%)	0.02	0.4	1.3	3.3	7.9	12.6

In terms of units sold, the European physical music market has been in a state of decline in recent years, having been hit by unauthorised copying, both in physical and digital form.

However, the addressable consumer base for digital music in Europe is growing rapidly. The market is principally constrained by the availability of broadband Internet and the uptake of personal digital audio devices. Based on latest improvements in the fight against unauthorised copying and considering the high potential of digital music use on mobile terminals, the ScreenDigest study forecasts strong growth of the digital music market in the coming years as well as an increase of the physical music market after 2008.

Base case: digital music / physical music

Digitalisation of music and substitution to CDs is documented in a very detailed document published by the European Commission⁴⁸⁸. The study compares three scenarios:

- Physical retail of a CD (scenario 1)
- Online shopping of a CD (scenario 2)
- Online download of digital music (scenario 3)

The conclusion is that in scenario 1, the CD production phase is the most significant in terms of environmental impacts whereas in scenarios 2 and 3 the impacts related to the ICT equipment prevail. The study also suggests that electricity consumption and polystyrene production account for most of the impacts of producing CDs.

⁴⁸⁸ Digital Europe. The environmental and social impacts of digital music. 2003.
<http://www.forumforthefuture.org.uk/files/DigitaleuropeMusicasestudy.pdf>

Figure 65: Conclusions from the Digital Europe Study on Digital Music⁴⁸⁹

Box 3-15: Comparison of the results

Comparing the three scenarios, the figures tell only one story. Digital distribution (c) appears to be beneficial, with about 50 per cent less resource consumption than the other two scenarios. The physical retail (a) and online shopping (b) scenarios have similar impacts, with the online shopping scenario having a slightly lower material intensity. But the material benefits of digital distribution depend on the underlying assumptions. E.g. with a slow internet connection digital delivery can be up to several times more material intense than its physical counter-part (d). At the macro-level, the uncertainties linked to consumer behaviour make it difficult to recommend one delivery method over another. The table below highlights the three highest contributors to total material intensity (abiotic raw materials) in the scenarios assessed.

Table 3-4: Summary overview of the three highest contributors to total material intensity (abiotic raw materials).

	Physical retail (a) abiotic (kg)	Online shopping (b) abiotic (kg)	Digital distribution (partial capacity) (c) abiotic (kg)	Digital distribution (alternative settings) (d) abiotic (kg)
CD/CD-R	0.77	0.77	0.05	0.05
Production site				
NDC/ Warehouse				
CD shop/ Retailer shop	0.43			
Transport goods				
Transport by consumer	0.28			
Consumer PC materials		0.14	0.14	1.28
Download		0.25	0.46	4.14
CD burning				
Disposal				
Total	1.56	1.31	0.67	5.50

Unfortunately, the whole study is performed using the MIPS methodology (Material Input per Service Unit) which expresses the results of the environmental impacts analysis in terms of kg abiotic raw materials/ kg biotic raw materials and water consumption. Therefore, the net benefits of substituting physical CDs by digital equivalent could not be directly calculated with these results.

Methodology and assumptions:

The Digital Europe study provides an inventory of material and resources that are needed to produce CDs which serves as a basis for our energy and emissions savings estimates. Considering results of other case studies in the report, it is assumed that the impacts of the digital music ICT system itself are negligible compared to the impacts of physical music.

⁴⁸⁹ <http://www.forumforthefuture.org.uk/files/DigitaleuropeMusiccasestudy.pdf>

Figure 66: Materials and resources inventory for the production of 1 million CDs from the Digital Europe Study on Digital Music⁴⁹⁰

Material / Product	Unit	Amount per million CDs
Energy		
Electricity	kWh	159,484.0
Gas	m ³	5,340.0
Pre-products, Semi-finished products		
Polycarbonate (PC)	tonne	17.3
Aluminium	tonne	0.01
UV-Lacquer (acrylate)	tonne	0.1
Ink	tonne	0.2
Foil (PE)	tonne	1.0
Polystyrene (PS) (jewel boxes)	tonne	67.4
Paper (booklet + inlay)	tonne	23.2
Cardboard (Boxes for 25 CDs)	tonne	4.7
Other process input		
Tap water	m ³	331.2
Methanol	litre	41.6
Acetone	litre	35.3
Screen wash (Ink remover)	litre	60.0
NaOH	litre	187.5
HCl	litre	33.3
H ₃ PO ₄	kg	16.7
Nickel	kg	53.4
Nickelsulfamate	kg	14.1
Glass	kg	0.75

Based on this data, a simplified Life Cycle Assessment has been performed using the material and resource inventory, EcoInvent 1.3⁴⁹¹ life cycle data and the CML methodology. The analysis shows that the life cycle of producing one CD is associated to emissions of 392 g of CO₂ equivalents and consumption of 11.4 MJ primary energy (2.72E-4 toe). Calculations are detailed in Annexe 5.

Results

The results are provided for the substitution of one million CDs in **Table 158**.

Table 158 : Possible electricity and CO₂ eq. emission savings when substituting physical CDs by digital equivalents

⁴⁹⁰ <http://www.forumforthefuture.org.uk/files/DigitaleuropeMusiccasestudy.pdf>

⁴⁹¹ ecoinvent Centre (2004), ecoinvent data v1.3. ecoinvent reports No.1-25, Swiss Centre for Life Cycle Inventories, Dübendorf, 2004

	Savings in primary energy in toe	Emissions savings in kg CO ₂ eq.
Avoided production of 1 million CDs	272	392 000

■ Recommendations and evaluation of the option

This section aims at quantifying the potential benefits of physical music dematerialisation at the EU level. In order to forecast these estimates, the analysis is based on market data which were the only reliable data that could be found.

- BAU and Eco-scenario impact analysis at EU-level

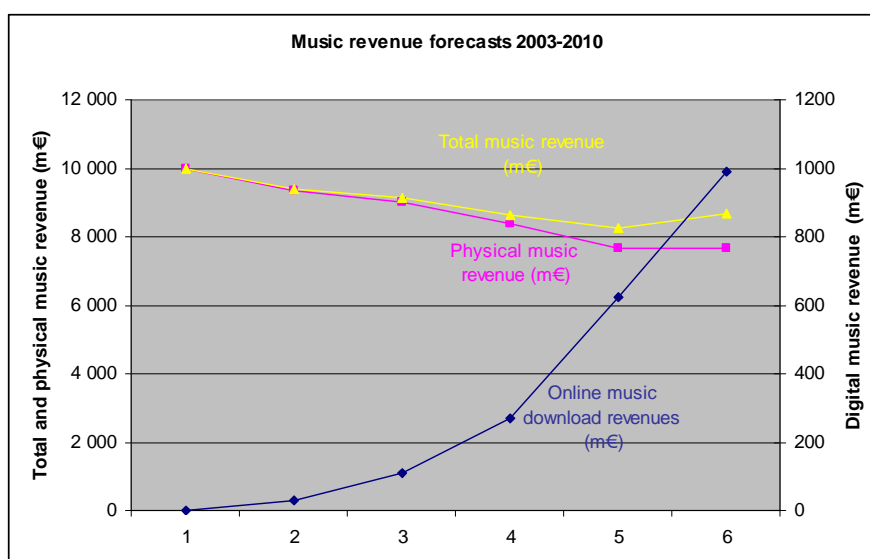
Sales projection and substitution ratio

The ScreenDigest study provides sales estimates from 2003 to 2006 and sales forecasts for 2008 and 2010 for digital and physical revenues in the EU. As no other data was available to distinguish between digital albums and single album sales, we assume that all online music download revenues correspond to album sales and used a conversion factor of 10€ per album and that one digital album equivalent substitutes to one physical CD.

Using album equivalent as a proxy to estimate substitution between digital and physical sales probably underestimates real savings as most of the digital sales are singles. In this context, a possible approach would be to consider that single tracks that are bought online substitute to singles CDs. However, with online digital library one can buy only one track of an album and it is not necessarily true that this track would be available as a physical single. The substitution ratio is therefore not straightforward but in the absence of complementary reliable data, using album equivalent provides interesting order of magnitudes of the savings that could be achieved through music dematerialisation.

Table 159: Online and physical music revenues in the EU: sales and forecasts from ScreenDigest study (number of sales in equivalent units calculated assuming a rate of 10€ per album)

	2003	2004	2005	2006	2008	2010
Online music download revenues (m€) ⁴⁹²	2.1	28	108	270	622	990
Number of sales in album equivalent (units) ⁴⁹³	210 000	2 800 000	10 800 000	27 000 000	62 200 000	99 000 000
Physical music revenue (m€)	9 991	9 348	9 031	8 367	7 651	7 678
Total music revenue (m€) ⁴⁹²	9 993	9 376	9 139	8 637	8 273	8 668
Growth rate of total music revenue	/	-6%	-3%	-5%	-4%	5%
Share of digital music on total music revenue	0%	0%	1%	3%	8%	11%



After continuous decrease from 2003 to 2008, ScreenDigest forecasts a 5% increase of the global music market after 2008. This forecast is explained by the overcome of some hindering factors for digital music uptake, continuous broadband penetration in the EU and a strong uptake of digital music on mobile systems. Following this trend, we assumed a 2.5% increase of the total music market from 2010 to 2020.

Both the BAU and ECO scenarios are based on ScreenDigest market data forecast up to 2010. However, where the BAU-scenario assumes a share of digital music on total music revenue of 20% in 2020, this figure is raised to 40% for the ECO-scenario. As no data was found on the number of tracks downloaded by subscribers to “all you can eat” platforms – and therefore on substitution benefits of this market– online subscription has not been included in the calculations.

⁴⁹² Results excluding online music subscriber revenues

⁴⁹³ Calculation based on online revenue assuming a price of 10€ per album

Savings are presented in **Table 160**.

Table 160: Electricity and emissions savings achieved through music CDs substitution in the EU

		2003	2005	2010	2020
BAU scenario	Number of digital sales in album equivalent (units)	210 000	10 800 000	99 000 000	221 000 000
	Share digital/physical	0%	1%	11%	20%
	Electricity savings in MWh	57	2 938	26 928	60 112
	Emissions savings in tCO₂eq	82	4 234	38 808	86 632
ECO scenario	Number of digital sales in album equivalent (units)	210 000	10 800 000	99 000 000	442 000 000
	Share digital/physical	0%	1%	11%	40%
	Electricity savings in MWh	57	2 938	26 928	120 224
	Emissions savings in tCO₂eq	82	4 234	38 808	173 264

According to IFPI in 2008⁴⁹⁴, 20 tracks are illegally downloaded for each track that is legally acquired. From a strict environmental perspective, it is likely that illegal downloads contributes to music substitution to a certain extent. However, keeping in mind that some of the tracks that are illegally downloaded would never have been legally bought by pirates and that no reliable data on illegal downloads could be found, unauthorised copying and music dematerialisation were not included in the analysis.

- Recommendations

Despite impressive growth, there is strong evidence that the digital market potential is still very high.⁴⁹⁵ The ScreenDigest study has identified six barriers to further expansion of digital contents:

- technology issues (mainly consumer access to enabling technologies)
- copyright issues (including difficulties in accessing content, due to the definitions of new media exploitation rights, terms of trade and collective management of rights)
- digital unauthorised copying issues (including the disparity of legal means to fight unauthorised copying in the different Member States)
- legal and regulatory issues (including the regulation of new media services and non-linear content services)
- competition issues (including gatekeeping issues in the value chains)
- various economic issues (including access to funding, skills, cost of digitisation, consumer acceptance, etc.).

⁴⁹⁴ IFPI (2008), Digital Music Report

⁴⁹⁵ Interactive content and convergence: Implications for the information society.2006. http://ec.europa.eu/information_society/eeurope/i2010/docs/studies/interactive_content_ec2006.pdf

Figure 67: Summary of main hindering factors for digital distribution market of interactive contents from Screen Digest⁴⁹⁶

	Today (2006)	Short term (2008)	Mid term (2010)
Broadband penetration	xxx	x	
Mobile content penetration	xxx	xx	x
Circulation of content rights - terms of trade	xxx	x	x
Piracy offsetting digital revenues	xxx	xx	xx
Collective management of rights	xx	xx	x
Consumer acceptance	xx	x	x
Skill and management challenges	xxx	xx	x
VAT distortion issues	x	x	x
DRM interoperability	x	xx	x
New media regulation	x	xx	xx

While most of these factors were not found to effectively block digital distribution market, they might slow down market developments. Hence tackling these issues will have positive impacts on the uptake of interactive content dematerialisation. Based on ScreenDigest and IFPI data, unauthorised copying appears to be the main issue to tackle in order to accelerate the uptake of the digital music market even if from a strict environmental perspective one can assume that illegal downloads also contributes to music dematerialisation.

- Other environmental effects (large scale)

No significant rebound effect was identified as once a digital music library is available online, the increased number of users will have little effect on the ICT infrastructure.

3.1.4.4 E-books/e-zines/ e-papers

Switching from a paper based book or magazine to a reading on a computer screen, PDA, or using another type of electronic support is now possible.

Two types of electronic books/magazines/newspaper exist: web based where the reader reads the material (e.g. book, news, etc.) online, or through the use of an “e-reader”, a dedicated device which display text (Figure 69).

⁴⁹⁶ Higher is the number of “x”, bigger is the scale of the phenomenon

Figure 68: Traditional news paper, web-based and news provided on an e-reader ⁴⁹⁷



Some companies have developed e-book readers (e-readers) capable of storing the equivalent of hundreds of books into the same digital media. However, standard e-books are still under development and an e-book for one e-reader might not be readable on another. Other barriers to overcome in order to expand the number of e-readers users are linked to general limitations of e-books and e-zines such as:

- PCs are not conducive to long sessions of reading text from a screen.
- Lack tactile appeal and “atmosphere” of conventional books.
- Limited number of titles available.
- Security and copyright considerations.

These electronic options allow reducing the impacts associated to book and magazine printing and distribution. However, many parameters influence the overall environmental impacts of e-books, e-zines and e-newspapers and a comparing the energy efficiency of these electronic media vs. the traditional paper based documents is a daunting task.

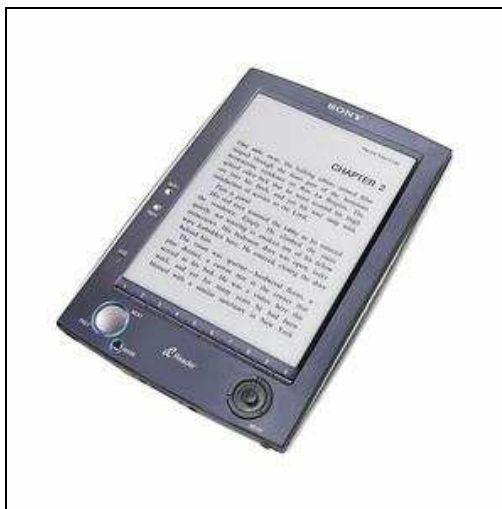
The two main parameters influencing the environmental impacts of e-documents are the time spent online, and the user’s tendency to print the electronic versions.

And in the coming years, such practice is not likely to have a high penetration rate in Europe as most customers prefer paper based documents: reading text on a screen and in search-equipped formats represents a profound behavioural shift which could require some time. As such, no case study⁴⁹⁸ and no scenario were reported for this ICT based practice.

⁴⁹⁷ Moberg et al. *Screening environmental life cycle assessment of printed, web based and tablet e-paper newspaper*. 2007. KTH Centre for sustainable Communications, Stockholm, Sweden

⁴⁹⁸ A very complete study comparing traditional and ICT based newspapers is available. It concludes that In the European context: printed newspapers produced 28kg of CO₂ per reader a year. Reading a web-based newspaper for 30 minutes a day produced 35kg of CO₂ per reader a year. At 10 minutes' use a day, a web-based newspaper produced 14kg CO₂ a year, including 8kg CO₂ a year caused by reading the site. Moberg et al. *Screening environmental life cycle assessment of printed, Web-based, and tablet e-paper newspapers* Royal Institute of Technology Sweden KTH Centre for sustainable Communications

Figure 69: Sony's e-book



3.1.4.5 Virtual Answering Machines

■ Description of virtual answering machines and related ICT applications

Several telephone network operators now offer an alternative to the conventional answering machine: the virtual answering machine in the network. Virtual answering machines in the fixed network function in a similar way to mailboxes in the mobile network: users set up their own personal call manager in the network according to their individual requirements. A notification function alerts users of new messages at a time of their choosing, either at a number they have given or by a text message to their mobile phone. These messages can be accessed by telephone, mobile phone or internet. Inversely, fax messages, e-mails, voice mails and text messages can be sent by computer. When retrieved by telephone, electronic messages and e-mails (including file attachments) are read out to the user, who can reply immediately. A previous German study⁴⁹⁹ indicates that replacing all 18 million conventional answering machines in Germany with virtual answering machines would save around 788 GWh per year. This value could be further increased by using the fax function and so saving the power consumed by conventional fax machines in stand-by mode.

However, no statistical data on the current and future number of physical answering in Europe machines is available to estimate the impact of such substitution (virtual vs. physical answering machine) at the scale of the whole European Union. Therefore, no scenarios were built to quantify the impacts of such ICT-application.

⁴⁹⁹ <http://www.wupperinst.org>

3.1.5. E-COMMERCE

3.1.5.1 Description of e-commerce and related ICT applications

E-commerce is a part of e-business. E-business can be defined as follows: “business processes, commercial activities, or other economic tasks conducted over the Internet or computer mediated networks (Intranet, etc.)”⁵⁰⁰. The OECD⁵⁰¹ provides the following definition: “Electronic commerce refers to commercial transactions occurring over open networks, such as the Internet. Both business-to-business and business-to-consumer transactions are included.” Further, it gives both a narrow and a broad definition of the commercial transactions related to e-commerce:

- Narrow definition: “An Internet transaction is the sale or purchase of goods or services, whether between businesses, households, individuals, governments, and other public or private organizations, conducted over the Internet. The goods and services are ordered over the Internet, but the payment and the ultimate delivery of the good or service may be conducted on- or off-line. “
- Broad definition: “An electronic transaction is the sale or purchase of goods or services, whether between businesses, households, individuals, governments, and other public or private organizations, conducted over computer-mediated networks. The goods and services are ordered over those networks, but the payment and the ultimate delivery of the good or service may be conducted on- or off-line.”

E-commerce can be applied to different sector through: e-retailing (online sale of tangible goods); online gambling (casino and card games, sports and other betting, lotteries); pharmacy/e-health (online sale of drugs, medicines, and other healthcare products); telecommunication services (from mobile phone contracts and pre-paid phone cards to website hosting services); and travel (travel services, packaged holidays, car rentals, etc.) which appear to be at the forefront of e-commerce⁵⁰².

Information technologies and e-commerce are transforming manufacturing (e.g. digitalisation of products) and distribution processes. In doing so, it has the potential to reduce or eliminate the need for products, for warehouses and retail stores, and energy, space and material they consume. Moreover, at first glance, it could have beneficial effects on transport. However the rebound effects related to e-commerce may also be considerable: efficiency gains achieved in production processes could be offset by increased consumption of products, material and energy, and growing traffic.

⁵⁰⁰ Source : Klaus Fichter. *E-Commerce Sorting Out the Environmental Consequences*. MIT press, Journal of Industrial Ecology, 1 April 2002, vol. 6, no. 2, pp. 25-41(17)
<http://www.mitpressjournals.org/doi/pdf/10.1162/108819802763471762>

⁵⁰¹ OECD Glossary of statistical terms <http://stats.oecd.org/glossary/index.htm>

⁵⁰² Pago Report 2007 <http://www.pago.de/Pago-Report-2007-E-Commerce-i.3441.0.html>

Table 161 provides an overview of the different applications of e-commerce and of their related potential environmental impacts.

Table 161: Overview of main e-commerce applications and related potential environmental effects

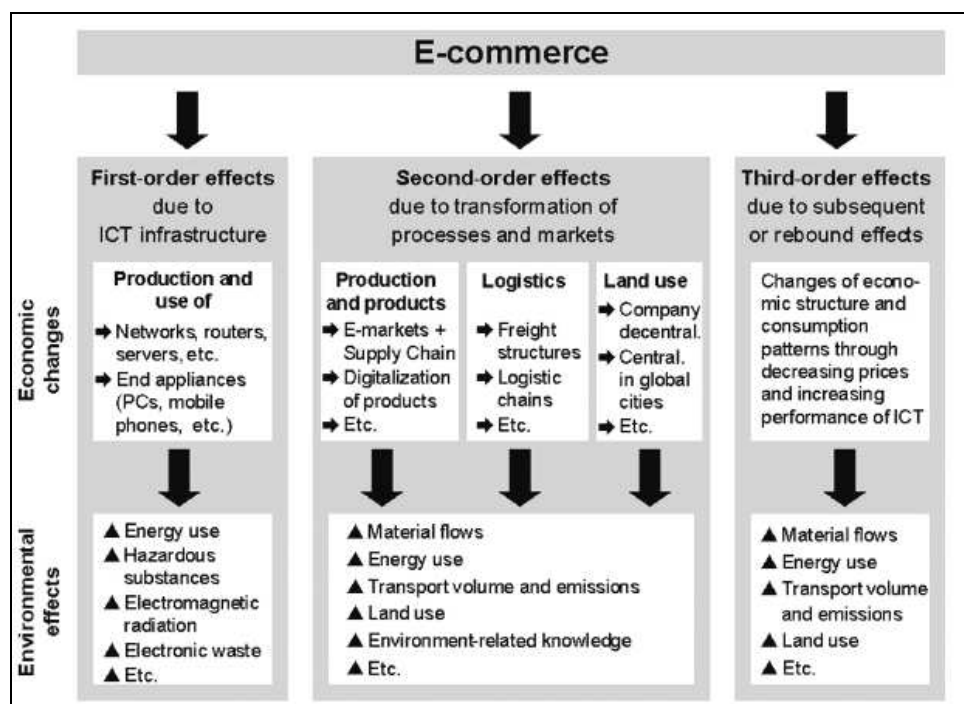
Application	Main equipment involved	Potential environmental effect* +: positive -: negative ±: uncertain
B2B e-commerce	internet infrastructure computer/laptops/ peripherals RFID tags Dedicated software	+: reduction of overproduction +: reduced paper consumption +reduction of inventory levels ±: distribution distances of supplies +: optimisation of transport of supplies (capacity) ±: possible increase in airfreight use
B2C e-commerce of a virtual good or service	internet infrastructure computer/laptops/ peripherals	+: reduced transport +: reduced raw material consumption ±: printed materials ±increased consumption
B2C e-commerce of a physical good	internet infrastructure computer/laptops/ peripherals	+: reduced transport to the store +: possible reduction of heating/cooling energy if the product is sold directly from the warehouse (websites instead of stores) ±: environmental impacts of the distribution phase -: increased packaging ±increased consumption

Three main categories of environmental effects of e-commerce can be distinguished⁵⁰³:

- First order effects linked to the necessary ICT infrastructure (PC, mobile phones, servers, routers, etc.) leading to energy consumption and production of electronic waste.
- Second order effects by reshaping economic processes and markets (e-markets, virtual business networks, digitalisation of products) which has consequences on the use of resources, transportation, and land use (either beneficial or damaging to the environment).
- Third order effects by causing structural changes of the economy, affecting lifestyles and consumption patterns which in turn can affect the environment (rebound effects).

⁵⁰³ Source : Klaus Fichter. *E-Commerce Sorting Out the Environmental Consequences*. MIT press, Journal of Industrial Ecology, 1 April 2002, vol. 6, no. 2, pp. 25-41(17)
<http://www.mitpressjournals.org/doi/pdf/10.1162/108819802763471762>

Figure 70: Environmental effects of e-commerce⁵⁰⁴



Environmental benefits of e-commerce and its impacts on the overall energy efficiency of various sectors are part of the secondary effects of e-commerce (see Figure 70). Examples of third order effects are the impact of the energy and packaging material used by the logistics networks for product fulfilment and delivery (increase number of shipped goods, increase use of packaging, and transportation, etc.).

An integrated e-commerce scenario combines retail online sales with B2B e-commerce methods for procurement of material and components, along with the management of the product's end-of-life. Combining B2B and B2C e-commerce could potentially provide energy savings from reduced manufacturing waste, overproduction, and warehousing, as well as savings in recycled materials. Above all, potential seems to rely in the fields of demand and supply chain management, e-procurement where quantities procured or stored, surplus production and error rates between supplier and manufacturer could be reduced.

3.1.5.2 Analysis of the policy framework at EU level, business initiatives, analysis of the e-service status and trends in the EU

■ Status

⁵⁰⁴ Source : Klaus Fichter. *E-Commerce Sorting Out the Environmental Consequences*. MIT press, Journal of Industrial Ecology, 1 April 2002, vol. 6, no. 2, pp. 25-41(17)
<http://www.mitpressjournals.org/doi/pdf/10.1162/108819802763471762>

The eEurope Action Plan Benchmarking report 2001 shows that, in Europe, fewer than 5 % of Internet users make online purchases regularly; equivalent to 1.7% of the population. Eurostat data shows that in 2006, 21 % of the population (EU 25) regularly purchase or order items online (B2C). B2B commerce is also developed with 15% of businesses having received orders online in 2006 (EU 25). Worldwide, for the years 2002-2003, more than three quarters of all online sales and purchases were in the B2B sector⁵⁰⁵.

Table 162: Information society e-commerce indicators⁵⁰⁶ (2006)

Percentage of individuals having purchased/ordered online in the last three months EU 25	21.0%
Percentage of enterprises having received orders online within the previous year EU 25	15.0%
Percentage of enterprises having placed orders online within the previous year EU 10 (source e-business w@tch 2006 ⁵⁰⁷)	48.0%

Statistics (Figure 71) show that e-commerce still represents a low proportion of the overall trade turnover (2.7%, 2.8% and 4 % in EU 25 respectively in 2004, 2005, and 2006⁵⁰⁸). E-commerce will not represent 100% of the total turnover in the future, but will certainly gain in importance, partly due to the increase of internet users.

⁵⁰⁵ Source : Klaus Fichter. *E-Commerce Sorting Out the Environmental Consequences*. MIT press, Journal of Industrial Ecology, 1 April 2002, vol. 6, no. 2, pp. 25-41(17) – Also in USA, in 1998, B2B transaction accounted for 84% of all internet transactions (IPTS ESTP 2000)

<http://www.mitpressjournals.org/doi/pdf/10.1162/108819802763471762>

⁵⁰⁶ EUROSTAT

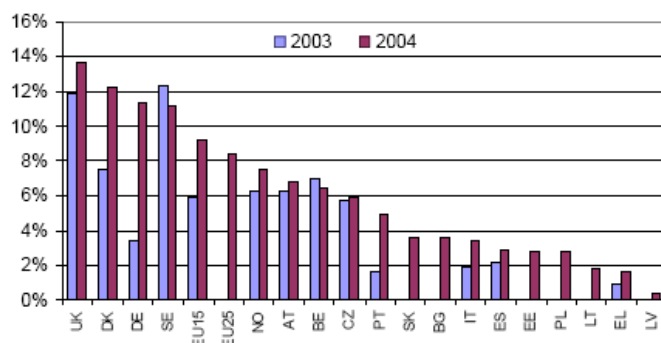
http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/I/15&language=en&product=Yearlies_new_science_technology&root=Yearlies_new_science_technology&scrollto=0

⁵⁰⁷ http://www.ebusiness-watch.org/key_reports/documents/EBR06.pdf

⁵⁰⁸ EUROSTAT Percentage of enterprises' total turnover from E-commerce via Internet in EU 25

http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=Yearlies_new_science_technology&root=Yearlies_new_science_technology/I/15/ir080

Figure 71: E-commerce revenues as a percentage of enterprises' total turnover in 2003 and 2004⁵⁰⁹ (2006 data not complete)



Concerning the B2B area, which represents more than three quarters of all online sales and purchases⁵¹⁰, the 2006 e-business w@tch survey shows that, in EU 10, about 50% of all firms active in one of the ten sectors⁵¹¹ surveyed said that they placed at least some orders to suppliers online. The incidence increases by firm size (see Table 163). The e-procurement adoption rate is highest among ICT-related industries and in hospitals (with about 70% of firms). In the footwear and the food & beverages industry, comparatively few companies place orders online.

A significant percentage of firms that place orders online said that these orders accounted for less than 5% of their total procurement (share of e-procurement as a percentage of the total procurement volume). About one in four companies (out of those placing orders online) said that online orders account for more than 25% of their total orders to suppliers. The survey also reports that only 10 % of the firms in the ten sectors use software solutions of internet-based services for e-procurement, meaning there is a gap between the share of firms placing at least some orders online (about 50%) and companies using a dedicated software for this (10%). Therefore it can be assumed that most companies place orders through websites or extranets of suppliers (e.g. intranet that is partially accessible to authorised outsiders) and that the digital back-office integration of procurement processes is not in an advanced state.

⁵⁰⁹ 2005 *Information Society Benchmarking Report*, European Commission
http://ec.europa.eu/information_society/eeurope/i2010/docs/benchmarking/051222%20Final%20Benchmarking%20Report.pdf

⁵¹⁰ For the years 2000-2003 according to Fitcher, K. *E-Commerce: Sorting out the Environmental Consequences*. 2003, *Journal of Industrial Ecology*, Vol. 6, Number 2.

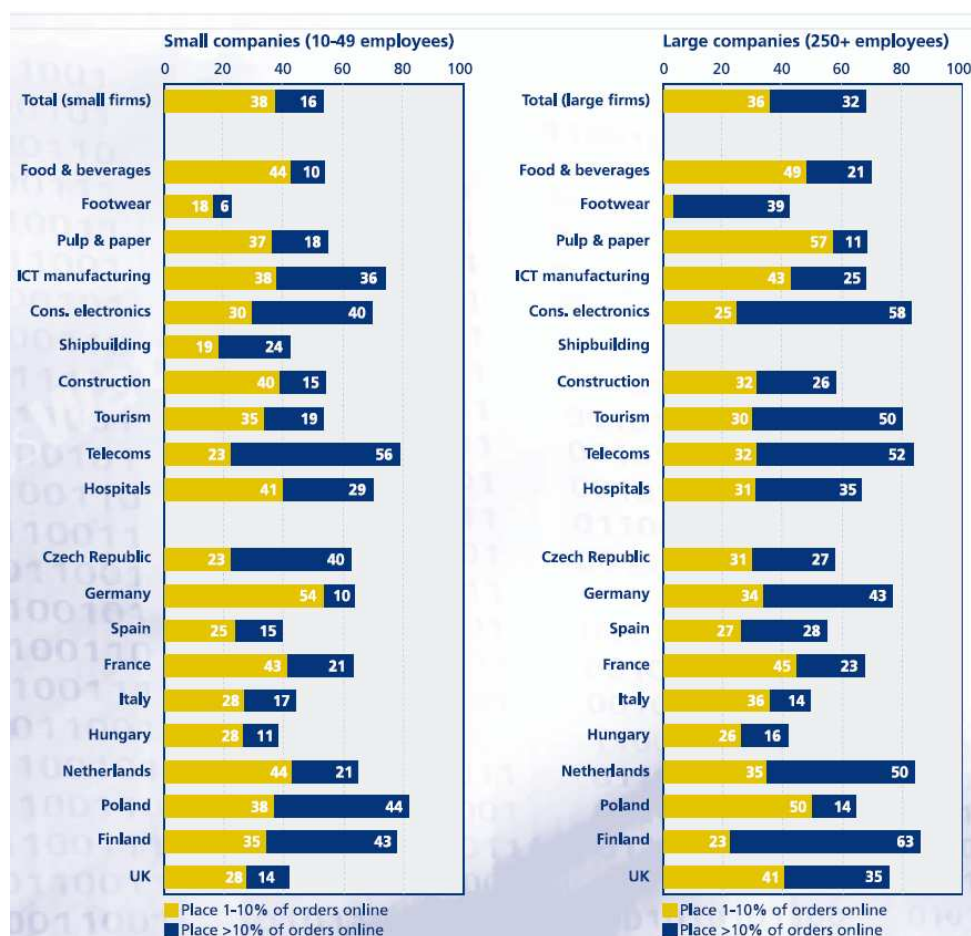
⁵¹¹ Food and beverages, Footwear, Pulp and paper, ICT manufacturing, Consumer electronics, Shipbuilding and repair, Construction, Tourism, Telecommunication, Hospital activities

Table 163: Companies ordering supply goods online⁵¹²

	Place orders online		Place 1-25% of orders online		Place more than 25% of orders online		Use specific ICT solutions for e-sourcing	
	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms
Weighting scheme:								
Total (EU-10)	57	48	74	75	26	25	16	9
By firm size								
Micro (1-9 empl.)		44		73		27		7
Small (10-49 empl.)		54		80		20		10
Medium (50-249 empl.)		60		76		24		16
Large (250+ empl.)		68		75		25		29
By sector								
Food & beverages	54	39	86	91	14	9	14	5
Footwear	35	29	83	87	17	13	9	5
Pulp & paper	59	49	81	75	19	25	14	8
ICT manufacturing	72	69	67	49	33	51	20	10
Consumer electronics	70	71	60	47	40	53	16	9
Shipbuilding & repair	62	53	78	69	22	31	18	12
Construction	53	51	74	72	26	28	12	6
Tourism	60	39	77	72	23	28	20	12
Telecommunication	78	77	54	49	46	51	26	12
Hospital activities	67	67	71	73	29	27	19	12
Base (100%)	firms using computers		firms placing orders online		firms placing orders online		firms using computers	
N (for total, EU-10)	7237		4224		4224		7237	

⁵¹² Source : E-business w@tch 2006 http://www.ebusiness-watch.org/key_reports/documents/EBR06.pdf

Figure 72: Companies ordering supply goods online (detail per country)⁵¹³



The 2006 e-business w@tch survey also provides data related to the B2C area (see Table 164). About 25% of the companies surveyed enable customers to place orders online. Within these companies, a majority (70-90% depending of the sector) reported that the orders received online represented up to 25% of their total orders. Results also show that e-commerce share is higher in ICT related industries (ICT manufacturing, telecommunications) and in tourism. For some sectors such as Footwear, the need for the customer to be sure of the size of the purchased item makes it less likely that e-commerce will be expanding significantly comparatively to others (e.g. telecommunication) in these sectors.

In 2005, 23% of private individuals placed online orders (21 % in 2006, see Table 162). Customers most often used the internet for ordering books and making travel arrangements (Table 165). Around 8% of persons declared having bought books and an almost identical percentage claimed to have made travel arrangements online. Other products most often bought on the internet include clothes and sports goods, movies

⁵¹³ Source : E-business w@tch 2006 http://www.ebusiness-watch.org/key_reports/documents/EBR06.pdf

and music⁵¹⁴. Online shopping of groceries and household goods is not very important yet.

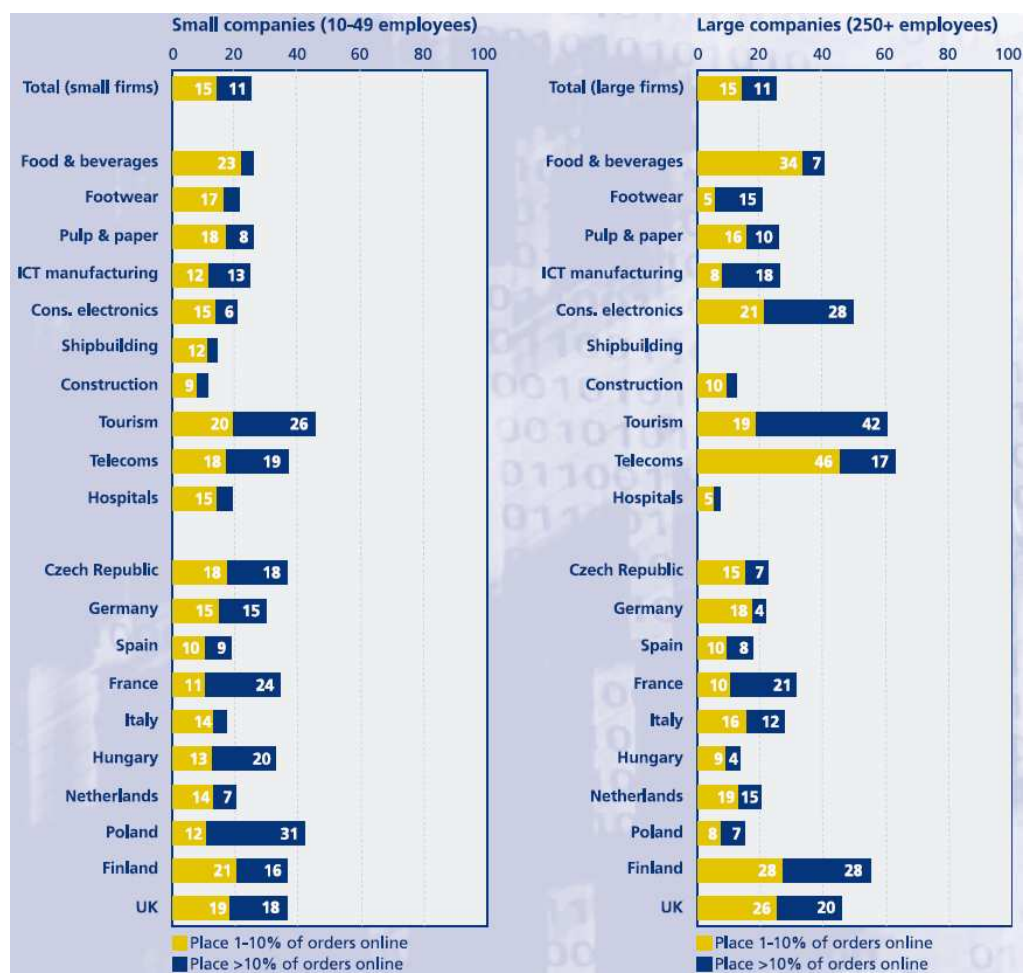
Table 164: Companies receiving orders from customers online⁵¹⁵

	Accept orders from customers online		Receive 1-25% of orders online		Receive more than 25% of orders online		Use specific ICT solutions for e-selling	
Weighting scheme:	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms
Total (EU-10)	35	25	73	75	27	25	18	9
By firm size								
Micro (1-9 empl.)		23		79		21		6
Small (10-49 empl.)		26		76		24		12
Medium (50-249 empl.)		29		75		25		16
Large (250+ empl.)		26		74		26		27
By sector								
Food & beverages	31	19	82	87	18	13	14	4
Footwear	25	23	86	88	14	12	8	5
Pulp & paper	26	28	78	77	22	23	19	11
ICT manufacturing	26	27	55	64	45	36	24	12
Consumer electronics	25	35	90	66	10	34	20	12
Shipbuilding & repair	18	14	100	100	0	0	12	8
Construction	13	11	84	88	16	12	8	5
Tourism	49	36	68	72	32	28	28	11
Telecommunication	36	40	66	63	34	37	37	21
Hospital activities	7	10	83	83	7	17	8	8
Base (100%)	firms using computers		firms accepting orders online		firms accepting orders online		firms using computers	
N (for total, EU-10)	7237		1994		1994		7237	

⁵¹⁴ EUROSTAT. Statistics in focus, Use of the internet among individuals and enterprises 2006.
http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NP-06-012/EN/KS-NP-06-012-EN.PDF

⁵¹⁵ Source : E-business w@tch 2006 http://www.ebusiness-watch.org/key_reports/documents/EBR06.pdf

Figure 73: Companies receiving orders from customers online (detail per country)⁵¹⁶



⁵¹⁶ Source : E-business w@tch 2006 http://www.ebusiness-watch.org/key_reports/documents/EBR06.pdf

Table 165: The goods and services most frequently purchased on the Internet by private individuals in 2005 (%)⁵¹⁷

	EU25	EU15	BE	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK	IS	NO
% of persons who bought in the last 12 months	23.1	27.2	16.3	5.5	48.0	42.4	6.8	2.5	11.7	:	:	5.9	5.1	4.8	2.2	39.0	8.1	:	:	25.3	6.9	5.8	u	9.0	38.0	50.3	44.1	44.0	
Books/ magazines/e-learning	7.9	9.3	:	1.6	10.9	16.9	2.3	0.8	1.9	:	:	1.6	2.0	0.7	0.8	24.1	3.0	:	:	10.0	2.9	1.9	u	2.6	8.5	12.2	14.4	16.1	
Travel and holiday accommodation	7.8	9.7	:	0.7	17.7	10.0	2.2	0.4	4.9	:	:	2.0	1.3	0.8	0.4	16.7	1.7	:	:	3.4	0.6	0.9	u	1.7	10.0	16.3	23.5	31.1	
Clothes, sports goods	7.5	9.1	:	1.1	13.7	16.9	2.4	0.4	1.0	:	:	1.0	1.0	0.6	0.2	10.3	1.2	:	:	7.4	1.6	1.1	u	2.9	10.5	12.8	14.8	8.7	
Films/music	7.4	9.0	:	0.5	11.3	11.1	u	0.4	1.5	:	:	1.1	1.2	1.0	0.5	15.5	1.6	:	:	4.9	1.4	1.5	u	1.1	6.8	12.7	23.4	12.3	
Tickets	5.6	6.9	:	:	4.6	11.2	u	0.3	:	:	:	0.5	0.4	0.8	0.1	7.7	0.7	:	:	4.1	1.0	u	u	1.6	4.7	3.0	11.2	8.7	
Household goods	5.5	6.8	:	1.0	16.8	7.6	2.8	0.2	3.1	:	:	0.9	0.1	0.6	0.5	12.4	1.6	:	:	3.9	0.6	1.4	u	0.8	8.5	9.1	15.9	11.0	
Electronic equipment	4.6	5.4	:	2.1	8.6	8.6	u	0.3	1.2	:	:	1.0	0.9	1.4	0.1	7.3	0.9	:	:	4.4	1.6	1.1	u	1.0	4.4	7.3	10.2	4.8	
Computer software	4.2	5.0	:	0.4	8.5	7.3	u	0.2	1.2	:	:	1.0	1.1	0.5	0.4	8.6	1.4	:	:	2.7	1.2	1.1	u	1.1	3.9	3.8	10.9	8.5	
Computer hardware	3.5	4.2	:	0.3	10.3	5.8	u	0.6	1.2	:	:	0.8	0.7	0.4	0.2	5.9	0.8	:	:	2.2	1.3	0.9	u	0.6	5.9	5.5	8.3	4.4	
Food/ groceries	2.3	2.8	:	0.2	3.3	2.5	u	0.0	1.0	:	:	0.4	0.3	0.1	0.1	3.1	0.5	:	:	1.8	1.2	u	u	0.2	u	0.7	8.7	2.2	
Shares/ Financial services/ insurance	2.2	2.8	:	u	2.4	2.0	u	0.1	0.6	:	:	0.5	0.4	0.1	0.1	2.6	0.4	:	:	0.5	0.3	0.7	u	0.2	2.4	2.7	9.3	3.1	

Source: Eurostat, Community survey on ICT usage and electronic commerce in enterprises.

N.B.: Data not available for FR, IE, MT, NL, NO.

* rate expressed as a percentage of the total number of individuals.

u = data not reliable.

■ Policy framework and business initiatives

E-commerce in Europe is mainly influenced by the following policies:

- The eCommerce Directive 2000/31/EC (2000) is Europe's basic legal framework for electronic commerce in the Internal Market
- The Directive (2001/115/EC) on VAT Invoicing which ensures all Member States' tax authorities recognise the validity of electronic invoices
- The Directive 2002/38/EC on VAT rules on radio and television broadcasting services and certain electronically supplied services mean that EU suppliers no longer have to charge VAT when supplying digital products to countries outside the EU, as was the case before e-service existed
- Other policies related to electronic money and digital signatures also influence e-commerce (e.g. Directive 1999/93/EC on a Community framework for electronic signatures)

■ Trends

E-commerce will not represent 100% of the total turnover in the future, but will certainly gain in importance. European e-commerce is expected to grow as a result of several important trends:

- Continued growth in the internet user population, which contributes to the expansion in the number of potential internet buyers

⁵¹⁷ http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NP-06-012/EN/KS-NP-06-012-EN.PDF

- Consumers now have several years of experience with e-commerce, encouraging veteran internet users who are comfortable navigating the internet to shop and purchase online
- Consolidation in the dot-com sector, resulting in a smaller number of dominant retailers and portals, limiting competition but enabling higher quality sites, more effective marketing, and increasingly better customer service
- Easier cross-border trading, which is likely to facilitate e-commerce purchases for consumers, particularly those in the Euro-zone

In the coming years⁵¹⁸, the number of Europeans shopping online will grow from 100 million (2006) to 174 million (2011). Their average yearly Net retail spending will grow from around €1,000 to €1,500, as UK Net consumers outspend even their US counterparts online. Overall, this will cause European eCommerce to surge to €263 billion in 2011, with travel, clothes, groceries, and consumer electronics all above the €10 billion per year mark.

3.1.5.3 Analysis of case studies and assessment of the improvement potential at a micro level

This section will present case studies where the practice of e-commerce has enabled savings in terms of energy and reduction of environmental impacts.

E-commerce relates both to B2B and B2C markets. In order to fully illustrate the potential of e-commerce, three situations are analysed:

- A B2B situation
- A B2C situation where a traditional store also performs online sales
- A B2C situation where the retailer exclusively sales online

The first situation refers to the potential of e-commerce applied to the B2B sector in terms of increased efficiency in all parts of the supply chain (i.e. sourcing and production, distribution, retail, and consumption). However, as no detailed case study was available to quantify the benefits of B2B e-commerce, data referring to a situation integrating B2B and B2C is analysed instead.

The second case study illustrates the benefits of online trade in the B2C sector, focusing on the savings made in the transportation of the goods through efficient delivery services.

Finally, the third case study allows assessing the full potential of e-commerce where warehouses stores combined with online purchases can replace traditional retail stores. This section analyses the sale of a tangible product as digital products were already analysed in section 3.1.4. .

⁵¹⁸ Forrester. *Europe's eCommerce Forecast: 2006 To 2011*. (June 2006)

■ Integrating B2B and B2C

E-commerce, and more specifically B2B online commerce presents an opportunity to change processes and markets with effects on sourcing and production, inventories, logistics, etc. An integrated e-commerce scenario combines retail online sales (B2C) with B2B e-commerce methods for procurement (e-procurement) of material and components, along with management of product reuse and recycling. Few data exist to assess the environmental effects of B2B e-commerce. However the following case study provides general indications on the potential improvement of the energy efficiency of production processes and sales in an industrial sector.

Case study: Computer manufacturing unit – integrating B2B and B2C e-commerce⁵¹⁹

Context:

This case study focuses on a computer manufacturing unit and explores three scenarios in order to assess the possible achievable energy reduction through e-commerce. In this case study, no specific data on the effects of B2B e-procurement was available. However it provides a general indication of the benefits of integrating B2B e-commerce practices with B2B e-commerce.

Methodology and assumptions:

The study's baseline analysis was a traditional commerce model for desktop computers, in which manufacturers predict demand based on sales data, mass produce machines, and then warehouse them and then ship them to intermediary warehouses, where they are then transported to retail stores.

In this scenario, consumers are assumed to transport their purchase home by car. The entire cycle from the manufacturer to the home consumes an estimated 6004 Mega Joules (MJ) of energy.

This baseline scenario was then compared to a model with an integrated e-commerce scenario (combining retail online sales (B2C) with B2B e-commerce methods for procurement (e-procurement) of material and components, along with management of product reuse and recycling) using airfreight and a third scenario integrating e-commerce methods and ground shipping.

Results:

The study shows that integrating B2B and B2C results in energy savings from reduced manufacturing waste, overproduction, and warehousing, as well as savings in materials reclaimed from old computers taken back by the producer.

⁵¹⁹ Results from Caudill, Reggie J., Luo, Yanchun, Wirojanagud, Pornsarun, and Zhou, Mengchu. *Exploring the Environmental Impact of eCommerce on Electronic Products: An Application of Fuzzy Decision Theory and Lifecycle Studies* 2000. Newark, NJ: Multi-lifecycle Engineering Research Center (MERC), New Jersey Institute of Technology. Published in *E-commerce and the Environment*, in Pamlin, D. (Ed.) Sustainability at the Speed of Light. Sweden: World Wildlife Fund, 2002.

In the e-commerce scenarios, total energy consumption is 5823 MJ if shipped by air and 5320 MJ if delivered by truck which corresponds respectively to a 3% or 11% energy savings and this illustrates the importance of transportation choices to reducing energy consumption.

Savings in terms of energy consumption related to raw material production and warehouse heating/cooling/lighting are the same for both e-commerce scenarios and total 291.4 MJ and are comparable to savings through reduced overproduction (292 MJ) (Table 166).

Table 166: Consumption for computer production and sales (in MJ)

	Traditional Model	Integrated Model with Air Shipping	Integrated Model with Ground Shipping
Materials	2913	2622	2622
Manufacturing			
- warehouse	2	1.6	1.6
- production	2920	2628	2628
Distribution (transportation from manufacturer to distributor to retailer)	105	587	84
Retail Store	4	3.5	3.5
Delivery to Consumer	60	2	2
Reuse/Recovery	0	-21	-21
Total Energy Consumed	6004	5823	5320
Percent Energy Saved		3% saved	11% saved

When only considering the benefits from B2B e-commerce (materials, manufacturing, distribution), the savings total 101.4 MJ when using airfreight and up to 604.4 MJ when using ground shipping.

Savings allowed by B2C e-commerce, induced by different sales and delivery systems compared to conventional computer retail are estimated to 58 MJ per computer.

Discussion of the results and conclusions:

There seems to be a potential to reduce energy consumption of manufacturing processes through e-commerce. However scarce data is available to precisely quantify the potential benefits of B2B practices.

However, other sources confirm that e-procurement and improved supply chains could provide benefits in terms of energy savings. In 1999, Toyota announced that its just-in-time delivery system (which uses the internet to determine which parts of a car are required and where, and at what time, and then converts this information into orders for hundreds of suppliers) was able to reduce plant inventories by 28% and energy-consuming warehouse space by 37%.

The study also indicates that energy savings could be achievable through the use of e-commerce for product reuse and recycling. Indeed, "reverse e-logistics" could help support the take-back of used goods. Internet is enabling new business models,

offering online services for extending the use and reuse of products. In the B2B market, HP has for example founded a remarketing unit which sells refurbished products to provide a low cost solution to some customers. However, these business opportunities are out of the scope of “dematerialisation”.

■ B2C Case Study: E-Grocery Shopping

According to past studies⁵²⁰, neither traditional nor e-commerce retailing show better environmental performance per se. The environmental performance very much depends on parameters such as shipping distances, return rates, shopping allocations, distance to retail stores, amount of packaging, and mode of transport. However, studies related to online shopping combined with home delivery of groceries reveal a different situation where electronic ordering of groceries and their joint distribution (typically the retailer or a third party takes care of the picking and also of the delivery of the goods to the customer) could provide the opportunity to organise grocery shopping in a more effective way.

Table 167 shows the environmental effects of e-commerce in the food production, distribution and consumption system. The effects of e-grocery shopping are highlighted in red.

⁵²⁰ Klaus Fichter. *E-Commerce: Sorting Out the Environmental Consequences*. Journal of Industrial Ecology 6 (2) , 25–41 doi:10.1162/108819802763471762 (2002)
<http://www.mitpressjournals.org/doi/pdf/10.1162/108819802763471762>

Table 167: Environmental effects of e-commerce and their implication for GHG emissions in the food production, distribution and consumption system

<i>Part of supply chain</i>	<i>Potential environmental effects of e-commerce</i>	<i>Effects on GHG emissions in food production and consumption system</i>
<i>Sourcing and production</i>	<ul style="list-style-type: none"> + Reduction of overproduction + Reduction of inventory levels ± Distribution distances of supplies 	<ul style="list-style-type: none"> Avoided emissions from food waste and unnecessary energy consumption Fewer warehouses needed, resulting in lower energy consumption Increased or decreased emissions from transportation (distances and mode)
<i>Distribution</i>	<ul style="list-style-type: none"> – Increased use of airfreight + Increased utilization of capacity + Avoided duplication of resources + Avoided unnecessary transport 	<ul style="list-style-type: none"> Higher emissions from the need for fast transportation Lower emissions from reduced traffic Lower energy consumption due to fewer warehouses
<i>Retail</i>	<ul style="list-style-type: none"> + Less waste of products ± Home delivery + Warehouses and websites instead of stores 	<ul style="list-style-type: none"> Avoided emissions from food waste and unnecessary energy consumption Lower emissions as traffic is reduced, but the consumers may use cars for other purposes Warehouses consume less energy than do stores
<i>Consumption</i>	<ul style="list-style-type: none"> + Possibility for decisions based on environmental information + Possibility for interaction with the supplier to make the whole chain more efficient 	<ul style="list-style-type: none"> Possibility for influencing the emissions from the whole supply chain, provided that interest in contributing to reduction of GHG emissions does exist
<i>Enabling technologies</i>	<ul style="list-style-type: none"> – Internet's own use of energy – Energy consumption of refrigerated reception boxes 	<ul style="list-style-type: none"> Higher emissions from increased energy consumption
<p><i>Note:</i> In the middle column, "+" indicates a change favorable to the environment whereas "–" indicates changes that are unfavorable.</p>		

E-grocery shopping appears to be an interesting area of B2C e-commerce as it relates to one of the largest retailing sector, and to stable consumer buying patterns: i.e. shopper may learn to use online ordering services quite quickly because of frequent use. Moreover, unlike clothing, groceries are bought without the need to see or test the goods before the buying decision is made.

The retailers and suppliers in the grocery industry estimate that the market share of electronic grocery shopping in Europe is between 5 and 10%⁵²¹.

Case Study: Dematerialisation Potential of electronic grocery shopping⁵²²

Context:

A Finnish study from the Ministry of Environment⁵²³ analyses how electronic grocery shopping could potentially change and reduce the material and energy intensity of grocery shopping compared with the traditional way of buying groceries.

⁵²¹ Hanne Siikavirta, Mikko Punakivi, Mikko Kärkkäinen, Lassi Linnanen. *Effects of E-Commerce on Greenhouse Gas Emissions: A Case Study of Grocery Home Delivery in Finland*. Journal of Industrial Ecology 6 (2) , 83–97 doi:10.1162/108819802763471807 (2002)
<http://www.mitpressjournals.org/doi/pdf/10.1162/108819802763471807>

⁵²² Mikko Punakivi. Comparing alternative home delivery models for e-grocery business. 2003. Helsinki University of Technology, <http://lib.tkk.fi/Diss/2003/isbn9512265826/isbn9512265826.pdf>

Electronic grocery trade (“ordering a basket of commodities over an electronic network (Internet, telephone, mobile phone, e-mail, fax)”) is currently a very small-scale business but is expected to reach 5-10% of the total grocery sales in Finland by 2010 (1% in 2001).

The ICT infrastructure already exists to support such growth but e-grocery shopping needs to attract more regular users to enhance the efficiency of e-grocery shopping operations and reduce the related environmental impacts. This can be contrasted with road transport where increase traffic results in congestions.

E-commerce in daily groceries is more demanding than many other physical products (e.g. books, clothing, footwear, etc.) because the trade of grocery goods is highly regulated and controlled in terms of preservation and quality. Grocery trade is more local than other sales over the internet, and unlike digital products delivered through digital channels, e-grocery shopping relies on physical distribution systems.

According to this study, the energy used in grocery transport from producers to retailers is almost (2-2.5 TWh/year) equal to the energy used in grocery transport from retailers to consumers (2-3 TWh/year).

A case study in Finland⁵²⁴ provides a good insight on the potential environmental benefits of e-grocery shopping combined with a home delivery system. This case study was chosen as it provides detailed data on the effects of online grocery shopping depending on various scenarios. Other case studies are available related to online grocery shopping however providing less recent data⁵²⁵. Most of the authors agree that the experience in the subject of online grocery shopping is not enough to draw definitive conclusions.

The area covered by this study is the Helsinki metropolitan area (135 km²) where it is estimated that the share of the distance driven for the purchase of daily goods is around 12% of the overall road traffic. This gives an indication on the potential reduction of GHG through food delivery services. The number of inhabitants in the test area is 202,000 and the number of households is about 89,000.

Methodology and assumptions:

Four different delivery systems were analysed through a simulation model (cases 1 to 4). Cases 1 and 2 require attended reception by consumer, while in case 3 and case 4

⁵²³ <http://www.ymparisto.fi/default.asp?contentid=85813&lan=en>

⁵²⁴ Mikko Punakivi. Comparing alternative home delivery models for e-grocery business. 2003. Helsinki University of Technology, <http://lib.tkk.fi/Diss/2003/isbn9512265826/isbn9512265826.pdf>

⁵²⁵ Farahmand, R., and M. Young (1998), “Home Shopping and its Future”, Paper presented at the 10th Annual TRICS Conference, 22-23rd September and Cairns, S. (1999), “Home Delivery Of Shopping: The Environmental Consequences”, TSU Working Paper 1999/5, University College London.

unattended reception is enabled through the use of customer-specific reception box⁵²⁶. A fifth case describes the current situation where customers use their own car for driving to the actual store where they do their shopping.

Data used for the simulation was derived from traditional grocery shopping point of sale data from one of the largest grocery retailers in Finland. The orders taken into account were limited to orders priced over €25 to provide a reasonable basket size for home delivery simulations. It was considered that the store has 1,450 customers and 1,639 orders a week with a minimum of 160 orders per day and a maximum of 462 orders per day. Also, it was assumed that customers lived in within the boundaries of the Helsinki metropolitan area.

Cases 1 to 4 are further detailed in Table 168.

Table 168: Description of the cases in the simulations

Case	Case Description
1	E-grocery home delivery in three two-hour time slots between 17:00 and 21:00
2	E-grocery home delivery in one-hour time slots between 12:00 and 21:00
3	E-grocery home delivery to reception boxes (see figure 3) between 8:00 and 18:00
4	E-grocery home delivery once a week per customer between 08:00 and 18:00 to reception boxes (simulating the best possible case from the E-grocer's point of view, where orders are sorted by postal codes and divided evenly on all delivery days)
5	All 1,639 "orders" delivered separately, simulating the situation where households do the shopping themselves using their own cars

The simulation model considered a fleet of vehicles with the following characteristics for the simulation of the routing and logistics:

- Maximum of 60 orders and 3,000 L volume of per route
- Working time maximum 11 hours per day and 5 hours per route
- Loading time per route: 20 min and drop-off time per customer: 2 min

Results:

Results show that the average distance driven per shopping trip is 6.9 km per order when considering the traditional shopping situation (case 5). The same data is given for the e-grocery shopping situations in Annexe 4/Figure 94. The distance travelled per order decreases when the flexibility given to the delivery operator increases. Unattended reception boxes lead to even higher reductions of the numbers of kilometres travelled. However, it should be kept in mind that unattended reception models requires extra electricity consumption to operate the receptions boxes, and this was not taken into account in the Finnish study.

⁵²⁶ A reception box is equipped with a refrigerator freezer unit, a room temperature compartment and is typically located in the customers' garage or yard. In this case study the energy consumption of the reception boxes is not evaluated but should be considered as part of the rebound effects.

When expressing the savings in terms of reduction of GHG emissions, the results show that there is potential to reduce the GHG emissions of traffic related to grocery shopping of 18 to 87%.

Table 169: Summary of the results

Case	Distance driven (km) per 1,639 orders	Reduction in distance driven compared with traditional retail	Vehicle type	GHG emissions tons of CO ₂ equivalent ⁵²⁷	GHG reduction compared with traditional retail
1	2676	76.5%	van, diesel	0.80	58.2%
2	5267	53.7%	van, diesel	1.58	17.7%
3	1525	86.6%	van, diesel	0.46	76.2%
4	822	92.8%	van, diesel	0.25	87.2%
5	11365	-	car, gasoline	1.92	0.0%

When extrapolated to Finland, and considering that current GHG emissions from grocery shopping represent about 1.4% of total Finland's GHG emissions, the authors estimated the theoretical maximum potential of e-grocery and home delivery (assuming e-grocery represents 100% of the market share for grocery shopping) could reduce the country's GHG emissions of 0.3 to 1.3 %.

Discussion of the results and conclusions

The results from the Finnish simulation provide a first indication of the potential for reduction of GHG emissions through e-grocery shopping. The study does not take into account the extra electricity consumption due to reception boxes in case of scenario case 3 and case 4. Also, it was assumed that the market share of e-grocery is 100%. However, in reality it only represents up to 10%⁵²⁸ of the grocery market and results should be decreased accordingly.

Additionally, it was assumed that all 1,450 customers (i.e. 1.6% of the households in the tested area) use their car to do 1,639 shopping trips per week. However a more realistic view should take into account that, on average only 55 % of all shopping trips are made by car. On average 31% of customers walk, 5% use public transportation and 8% use bicycles or other types of transportation means⁵²⁹.

It would be also important to include information on whether the customer goes to the store directly from home or on their way home from work or from another location. In this case the extra distance driven by the customers shopping should be taken into account.

⁵²⁷ Authors used emission factors of 168.594 g CO₂ eq. / km for a car (gasoline) and 299.5115 g CO₂ eq. / km for a van (diesel)

⁵²⁸ Mikko Punakivi. Comparing alternative home delivery models for e-grocery business. 2003. Helsinki University of Technology, <http://lib.tkk.fi/Diss/2003/isbn9512265826/isbn9512265826.pdf>

⁵²⁹ ibid

Finally another important aspect is the question of the shopping behaviour of the non-car owners. If they are the most likely users of home delivery services, the result might be extra traffic. However, according to a study conducted in 1999, 61 % of customers of home delivery services are car owners and 74% of them consider using their car less through e-grocery shopping services⁵³⁰.

Table 170 summarises the results of the Finnish case study.

Table 170: Summary of the effects of online grocery shopping – Finnish case study

Application	Daily savings from placing 1639 ⁵³¹ orders online			
	Transport (km)	Use of reception boxes	ICT equipment	Total savings in tons CO ₂ eq.
E-grocery home delivery in three two-hour time slots between 17:00 and 21:00	8,689	No	Not taken into account	1.11
E-grocery home delivery in one-hour time slots between 12:00 and 21:00	6,098	No	Not taken into account	0.34
E-grocery home delivery to reception boxes (see figure 3) between 8:00 and 18:00	9,840	Not taken into account	Not taken into account	1.46
E-grocery home delivery once a week per customer between 08:00 and 18:00 to reception boxes (simulating the best possible case from the E-grocer's point of view, where orders are sorted by postal codes and divided evenly on all delivery days)	10,543	Not taken into account	Not taken into account	1.67

■ B2C Case Study: Online Book Sale

Another aspect in terms of environmental benefits from B2C e-commerce, which is not illustrated in the Finnish e-grocery case study is that products sold directly from the internet (i.e. from a warehouse) could consume less energy per products than traditional retail-based sold products (this because a warehouse can contain far more products per square meter than a retail store and the needs in terms on lighting and heating are often reduced in a warehouse).

However, other parameters influence the energy consumption and environmental impacts of e-retailing such as the distance travelled by the good from the warehouse to the customer's residence, and the packaging needed when sending the good.

In order to provide an overview of the potential energy savings enabled by B2C e-commerce of tangible goods, this section provides a summary of results of a Japanese case study of an online book sale which compares the traditional book distribution

⁵³⁰ Cairns, S. *Home delivery: Environmental solution or disaster?* 1999

⁵³¹ According to the case study the supermarket receives about 1639 orders per day

channel to an online distribution channel. In introduction, a summary of previous findings related to B2C e-commerce is also provided. The Japanese case study was chosen as it appears to be the case study which takes into account the majority of the parameters influencing the environmental effects of B2C e-commerce, and also because books represent the most frequently bought good online⁵³².

This case study will not be transferable to all situations in Europe. However, it will provide a good insight of the potentialities of B2C e-commerce.

Case study: E-commerce of a book (Japan)⁵³³

Context:

The energy use associated with an online and conventional book retailing could be significantly different due to a number of criteria presented in Table 171.

Table 171: Parameters influencing the energy demand of book retail: online and conventional

Online book sale vs. conventional book retail	
Parameters favouring e-commerce	<ul style="list-style-type: none"> - Substitution of personal travel to and from retail shops with courier deliveries to homes affects transport energy. One expects that courier services should be more efficient. - E-commerce vendors do not need retail outlets, reducing building space and energy use in the commercial sector - E-commerce vendors may enjoy a lower rate of returns and unsold inventories, thus avoiding wasted production. Scarcity of relevant data makes this a very difficult issue to address.
Parameters favouring conventional retail	<ul style="list-style-type: none"> - E-commerce uses more packaging than the traditional model for many goods, inducing a degree of additional energy consumption for the production of packaging. - E-commerce entails increased energy consumption in residences due to additional time spent at home.

Several studies have addressed the question of the energy consumption of on-line and traditional retail models. The environmental impact of e-commerce depends on many factors as mentioned above. As a result, **depending on the situations considered, some studies conclude that e-commerce has a positive effect on the environment**

⁵³² Ernst & Young, (2000), Global Online Retailing, January – more details in Annexe 5/ Table 191

⁵³³ Williams E., Tagami, T. *Energy Use in Sales and Distribution via E-Commerce and Conventional Retail A case Study of the Japanese Book Sector*. Journal of Industrial Ecology. Volume 6, Issue 2 - Spring 2002
<http://www.mitpressjournals.org/doi/pdf/10.1162/108819802763471816>

and others estimate that it has a negative effect. More details are presented in Annexe 5/Table 192.

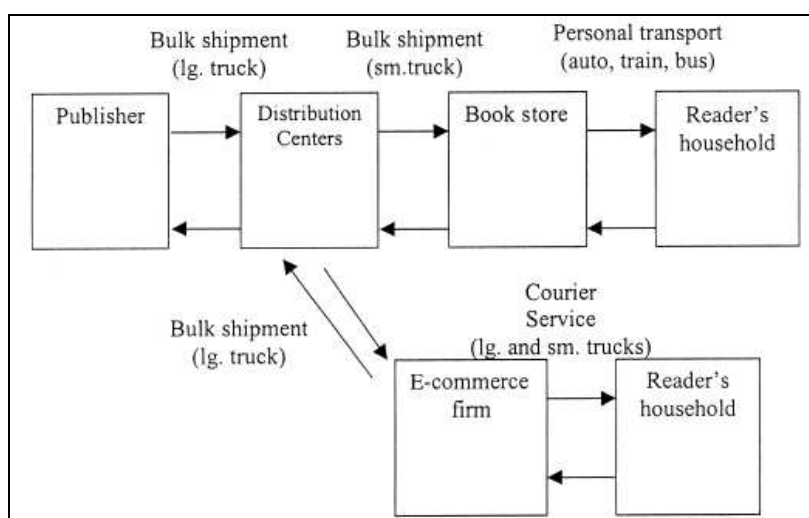
The present case study will explore in details the different parameters influencing the environmental impacts of e-commerce, in comparison with traditional retail.

Methodology and assumptions:

This study compares two scenarios for the sales and distribution of books. Based on Japanese statistics, the average number of books per order is 1.7. The study therefore calculates the energy consumption per book using an average of 1.7 books per order and comparing the following scenarios:

- B2C e-commerce: the consumers order the book via Internet at home and the good is delivered via courier services
- Conventional retail: consumers travel to the retail outlet, shop at the store and take the book back home. In this scenario it is considered that the customer undertakes a multipurpose shopping trip and only a fraction of the shopping trip is considered, in proportion to the share of total shopping expenses represented by books.
- The two scenarios differ by their sales and distribution systems (Figure 74)

Figure 74: Traditional and online sales and distribution channels



Finally, the study also evaluates the dependence of energy use on population density by considering 3 different regions in Japan: an urban region (Tokyo), a suburban region (Tochigi prefecture), and a rural area (Hokkaido prefecture). The population density can affect both the efficiency of distribution systems and the distance to the bookstore.

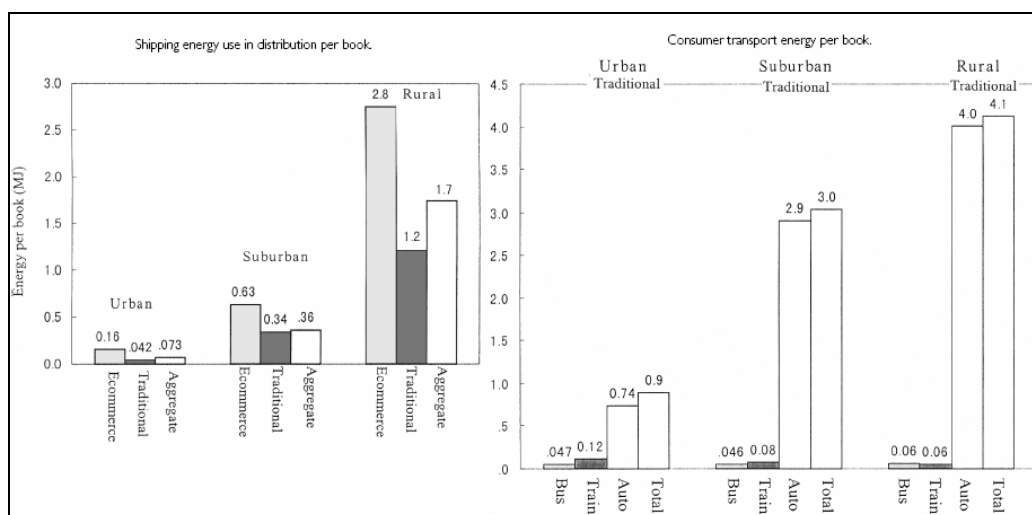
Results:

- Energy use by shipping and courier services
Results show that when considering the energy used for courier (e-commerce) and shipment (traditional commerce) services, the conventional scheme is more

efficient (Figure 75). This is mainly due to the fact that shipments deal with bulk packages involving less packaging and therefore can handle a larger number of books per volume. Also courier services must respond to quickly fluctuating loads and therefore are often not used at their optimal capacity. Lastly courier services sometimes make several attempts to deliver packages to individual homes.

However, consumer transport to the bookstore in the traditional book purchase scenario involves extra energy consumption. This energy used was calculated assuming multipurpose shopping trips and 0.8% (proportionally to economic expenditure) of the shopping trip energy use was allocated for book purchase.

Figure 75: Energy use related to transport (traditional scenario only) and distribution per book



- Energy use in production of packaging

The most significant difference in packaging between e-commerce and traditional retail lies in the delivery to the customer: on one side e-commerce uses small corrugated cardboard boxes for courier shipping, and on the other side conventional bookstores in Japan use paper bags, or light paper covers. Considering the production phase of the packaging only, the e-commerce scenario requires 3.9 MJ per order (i.e. 1.7 books) while the conventional scheme requires 0.8 MJ per order.

- Energy use at sales point: store vs. user's home

Energy is also consumed during shopping: either at the bookstore or at home (e-commerce). Previous studies suggested that the reduction of retail space implied

that e-commerce consumed less energy than conventional retail⁵³⁴. However, online shopping requires the use of a computer, of the internet and also induces increase in energy consumption for heating, and lighting the home of the online shopper.

The energy consumption per book related to the energy consumption of the retail store is calculated combining statistics on the energy consumption of a retail store, area of floor space and sales in book retail, and the study estimates that the energy consumption by stores is of 1.1 MJ per book.

For e-commerce, the energy consumption of an online book purchase was calculated by estimating the average power consumed by a computer (multiplied by the typical time for making an online purchase), and also by estimating the residential energy consumption related to lighting and heating of the home⁵³⁵. Assuming 1.7 books are bought per order, the average home energy use for online purchasing of one book is calculated to 0.95 MJ per book⁵³⁶.

When summing these results, the study concludes that e-commerce uses more energy than conventional retail (Figure 76) in all regions, but more significantly in dense areas, where the use of public transport favours traditional retail. The result that e-commerce uses more energy in rural areas is surprising: this result is due to the consideration of the multipurpose use of car trips.

If single purpose trips were considered, e-commerce would be more efficient in all regions⁵³⁷.

Considering a national scale (Japan) the aggregated results show that the average energy use in sales and distribution via online retailing is 5.6 MJ per book and for traditional retail 5.2 MJ per book, which suggest that the two systems are very similar.

Compared to previous studies⁵³⁸, the discrepancies in the results mainly come from the differences in the assumptions related to the shopping trip distances, and on

⁵³⁴ « A plausible estimate for the ratio of commercial building energy consumption per book sold for traditional stores versus online stores is 16 to 1 » according to Romm, J., A. Rosenfeld, and S. Herrman. *The Internet economy and global warming*. 1999. The Center for Energy and Climate Solutions.

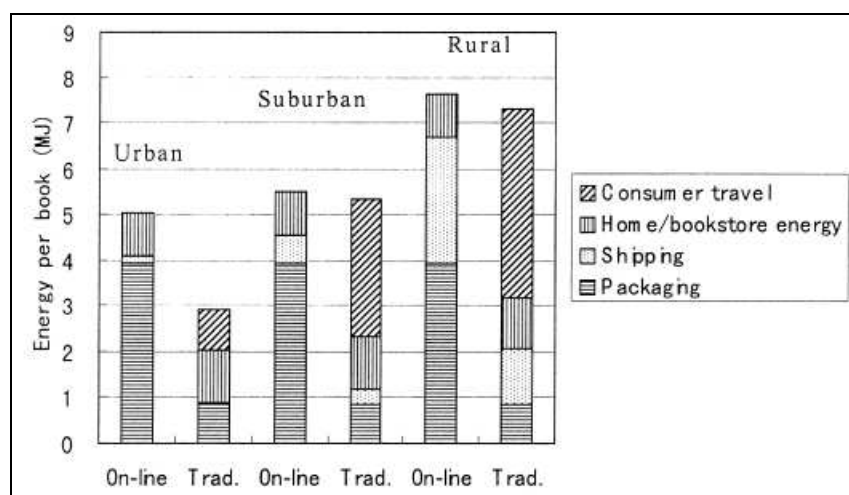
⁵³⁵ More details in Annexe 5 – Box 4

⁵³⁶ More details in Annexe 5 – Box 4

⁵³⁷ Assuming typical distances between the home and the bookstore of 0.5, 2.7 and 6.9 km in urban, suburban and rural areas respectively; the consumer energy use in travelling to and from the nearest store is 3.2, 17, and 44 MJ per book. These figures were calculated based on a typical fuel efficiency of 13 km/L and the energy content of gasoline was assumed to be 33 MJ/L, plus 28% for the production of the vehicle and fuel.

the packaging, and also to the percentage of energy use for transport allocated to the purchase of a book.

Figure 76: Total energy for sales and distribution per book



Discussion of the results and conclusions:

In this study, it is mentioned that two main factors, which could have an effect on the results, were neglected: the effects of online retailing on wasted production (it is being suggested that online retailing enables lower rates of returned books), and the rebound effects of induced consumption due to income saved from making an online purchase. However, both these aspects are very complex and would require a separate analysis.

Also e-commerce enables customers to be just “a click away” from purchasing and might encourage them to buy more.

Moreover, there could be a cascade effect where reducing the need to shop for books might reduce other shopping travels. However, specific studies on the transport behaviour of customers would be needed before drawing conclusions.

The results suggest that e-commerce is less favourable than traditional retail, even in rural areas. However, the authors specify that these results do not represent a final answer on the energy use of e-commerce but enable to identify where to set future energy conservation priorities (e.g. packaging, and packaging recycling seems to be an important issue, loading factors are also important as well as the optimisation of courier services, also if e-commerce and other home-based activities become important such as teleworking, then a greater priority on increasing energy efficiency in the residential building sector is needed).

⁵³⁸ In the US, Matthews et al. found that the energy use for sales and distribution of a book via e-commerce is of 73 MJ per book and 53 MJ via conventional retail.

■ Conclusions on the case studies

As the case studies illustrate, e-commerce has a great environmental potential to optimise transport logistics, reduce overproduction, manufacturing waste, warehousing space, etc. At the same time, e-commerce tends to accelerate the delivery of goods, leading to increase in courier, express, and parcel services. It also changes the structure of shipped freight individual delivery, thus leading to increased transport. Moreover, depending on the delivery service system, and on the purchase, the product bought via e-commerce can require non standard packaging and reduces the efficiency of vehicle load volume. The environmental effect of e-commerce will depend on how well it is optimised for specific conditions and no definitive conclusion can be drawn. Studies show that environmental savings depend on several local parameters, such as the load rate of vehicles and delivery distance.

Studies on e-shopping of books showed that the environmental impacts from e-commerce could be equal or smaller than those of traditional retail. The studies indicate that some key parameters such as shipping distances, return rates, population density, and shopping allocations have a decisive role for the environmental impacts of e-commerce. Human behaviour has a very important role in determining these parameters, since it is the consumer who decides on order sizes, supplier locations, product returns, and delivery time.

The overall environmental effects of e-commerce cannot yet be predicted, but it is obvious that e-commerce is not a neutral economy. The impact of the digital marketplace on the environment is thus uncertain and therefore no extrapolation scenarios are proposed for the EU until 2020.

3.1.5.4 Recommendations and evaluation of the option

■ Recommendations

The review of the available case studies leads to conclude that no new directives are needed in the short term.

However, interdisciplinary R&D on the total product life cycle (in an e-commerce scenario vs. a traditional scenario) should be encouraged:

- Indeed the studies available so far show that e-commerce is inherently neither environmentally friendly nor hostile. The need for more research on the environmental impact of e-commerce is particularly strong in the following domains:
- More case studies which would also allow for the identification of best practices for e-commerce applications
- Empirical studies involving a large number of companies in order to deliver results of statistical validity

- National and international monitoring programs to collect data on the environmental impacts of e-commerce
- So far the environmental effects of e-commerce are neither monitored nor managed. Therefore, a recommendation in order to develop sustainable e-commerce is to develop an environmental performance measurement tool (based on a LCA approach). The development of such tool however still faces methodical problems which need to be solved:
- Definition of the “functional unit” and of the scope for the analysis. System shifts might be required in order to capture the second and third order effects of e-commerce
- Synergetic effects should also be accounted for (i.e. some solution might not be very efficient at small scale but might perform better on a larger scale, e.g. delivery services in e-commerce systems)
- Availability of reliable data for the calculations

3.1.6. CONCLUSIONS

ICT services are known to be effective in reducing CO₂ emissions by helping to minimise the movement of people and goods and the use of paper and other office supplies.

The quantification of the energy savings enabled by ICT-applications in different sectors (e.g. e-government, e-commerce) is based on rough estimates as case studies reporting environmental benefits are scarce and rather report benefits in terms of economic parameters and time savings.

This can be explained as no standardised methods for calculating such environmental benefits exist in Europe. In Japan⁵³⁹ recently, a standard method⁵⁴⁰ to evaluate the benefits of ICT use in different sectors was developed and could serve for future reporting of ICT impacts.

Table 172 summarises the different savings obtained considering different scenarios.

Based on the calculated scenarios, the biggest potential to increase energy efficiency through dematerialisation seems to lie within the reduction of transport and office space needs through e-work practices and teleconferencing practices (respectively represent 70 % and 30 % of total savings calculated for dematerialisation) (Table 172).

It may be surprising to have savings under a BAU-scenario. This is because ICT solutions provide savings compared to non-ICT applications. Therefore, the BAU-scenarios provide an estimation of the savings enabled considering the current trends, compared

⁵³⁹ Japan Forum on Eco-efficiency

⁵⁴⁰ Guideline for Information and Communication Technology (ICT) Eco-Efficiency Evaluation
http://www.jemai.or.jp/JEMAI_DYNAMIC/data/current/detailobj-2687-attachment.pdf

to a baseline scenario where no further ICT-applications would be implemented. The Eco-scenarios provide savings which could be reached if ICT-applications are boosted by policy initiatives and business initiatives.

It should also be reminded that the scenarios implied necessary assumptions and that as such the methodology lead to some limitations (i.e. not all potential gains/drawbacks could be analysed). However, the results still provide a good order of magnitude. Also, the results only relate to a few of the areas included in dematerialisation. Indeed scenarios and quantification was only performed in areas where enough solid data was available and dematerialisation practices which uptake were too unreliable to predict (e.g. a practice strongly linked to human behaviours and preferences) were not analysed here.

For e-commerce, no quantification was possible as this practice can widely differ, depending on how the e-commerce channel is organised. More research is needed in order to reach conclusions.

Table 172: Summary of the estimated magnitudes of savings (secondary energy)

			Share of Dematerialisation Total	
	toe	tonnes CO ₂ eq.	toe	tonnes CO ₂ eq.
e-government (average)	4,984	33,908	0.20%	0.15%
e-government BAU	625	4,256	0.03%	0.02%
e-government Eco	9,342	63,560	0.33%	0.24%
teleconferencing average	708,699	8,435,764	28.94%	37.92%
teleconf. BAU	472,466	5,623,842	23.53%	31.68%
teleconf Eco	944,932	11,247,685	32.87%	42.47%
e-work average	1,725,657	13,636,730	70.47%	61.30%
e-work BAU	1,533,917	12,121,538	76.40%	68.28%
e-work Eco	1,917,397	15,151,922	66.70%	57.22%
e-ticketing (train) average	1,641	11,167	0.07%	0.05%
e-ticketing (train) BAU	597	4,061	0.03%	0.02%
e-ticketing (train) Eco	2,686	18,274	0.09%	0.07%
e-ticketing (movies) average	17	114	0.00%	0.00%
e-ticketing (movies) BAU	6	38	0.00%	0.00%
e-ticketing (movies) Eco	28	191	0.00%	0.00%
Digital Music average	7,753	129,948	0.32%	0.58%
Digital Music BAU	5,169	86,632	0.26%	0.49%
Digital Music Eco	10,337	173,264	0.36%	0.65%
			Share of EU 27 total (2020 projection) ⁵⁴¹	
	toe	tonnes CO ₂ eq.	toe	tonnes CO ₂ eq.
Dematerialisation⁵⁴² average	2,448,751	22,247,631	0.72%	0.50%
Dematerialisation BAU	2,007,611	17,753,734	0.59%	0.40%
Dematerialisation Eco	2,874,385	26,481,631	0.84%	0.59%

3.2. SUBTASK 3.2: MANAGEMENT AND PROCESS SUPPORT

3.2.1. INTRODUCTION

This task has the objective to analyse the energy efficiency potential of ICT applications in the field of management and process support. The focus is placed on the assessments of latest technologies and applications for ICT-enhancement in two main areas:

⁵⁴¹ Total 2020 EU 27 Electricity consumption projected to 3978 TWh (see Task 1) and total EU 27 CO₂ emissions projected to 4457.76 MtCO₂ (assuming the 20 % reduction compared to 1990 level is reached in 2020 and based on EEA data for the year 1990 (EEA - Annual European Community Greenhouse gas inventory 1990–2006 and inventory report 2008))

⁵⁴² The results only relate to a few of the areas included in dematerialisation as mentioned in the upper lines of the table

- Identification, tracking and tracing with radio frequency identification (RFID)
- Computer-aided design, simulation and virtual reality

For each of these two topics the study provides:

- Technical status and trends
- Case studies on ICT applications with energy saving potential

Finally we summarise and discuss the findings of the study which includes the following tasks:

- Systematisation of the identified technical trends
- Evaluation of policy options

3.2.2. IDENTIFICATION, TRACKING AND TRACING WITH RADIO FREQUENCY IDENTIFICATION (RFID)

3.2.2.1 Technical status and trends

Opportunities

According to the “European Policy Outlook RFID” paper, referenced at the European conference “RFID: Towards the Internet of Things” on the 25th and 26th of June 2007 in Berlin, RFID is providing the linkage between the “world of production” (represented by the material good) and the “world of service” (represented by digitalised information). With RFID tags, objects become “smart” and can be networked together and communicate with their environment. RFID technology as a precursor to the “Internet of Things” will optimise existing processes in various industrial sectors. RFID is also expected to create opportunities for new business models that will take advantage of a global network in which any object can be linked to any context.⁵⁴³

The working paper states important fields and industrial sectors for the application of RFID, which are:

- Manufacturing and production
- Transport and logistics
- Retail and consumer goods
- Public transport
- Health care
- Anti-counterfeiting
- Ticketing

⁵⁴³ RFID: The next to the Internet of Things, RFID – Outlook, Draft Paper, German Conference, Berlin, June 2007, online available at: http://www.rfid-outlook.pt/images/en/RFID%20Outlook%20paper_final%20version_240707.pdf

- ePayment
- (National) Security
- Recycling

These sectors can all benefit from RFID as a technology to optimise existing processes, improve reliability, offer new services and realise the advantages of rationalisation. With the growing availability of highly miniaturised passive and active transponders (RFIDs) including respective electronic scanner gates or sensors it is now possible to identify and localise goods within the supply chain very fast and even without visual contact. The main applications are therefore the identification, tracking and tracing of materials and goods in manufacturing, logistics and retail sales is increasingly based on RFID technology.

In conclusion the RFID technology has been recognised as a key technology for the efficiency improvement of technical and business processes. Although not stated in the above mentioned report, it seems justified to assume that RFIDs have potential to increase energy efficiency in such processes as well.

Challenges

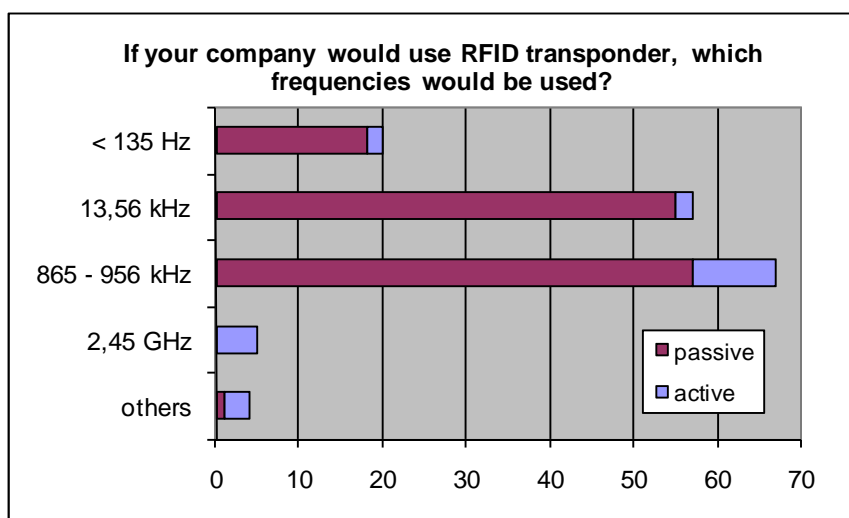
Two very recent studies [VDI News 2008⁵⁴⁴; P3/IPT 2008⁵⁴⁵] come to a more differentiated result. Both studies indicate that it is for the industry quite difficult to exploit the technical and economical efficiency potential of RFID solutions.

The RFID-Report 2008 [VDI News 2008] was based on a survey on 102 industry users of RFID technologies with together 493 RFID applications. According to this report, UHF passive transponders are the most commonly used RFID technology. Figure 77 below shows the results of the survey.

⁵⁴⁴ VDI News (11th April 2008): RFID-Report 2008 (in German only), Joint study by the German industry newspaper "VDI Nachrichten" in collaboration with the University of Freiburg.
<http://www.vdi-nachrichten.com/rfid>

⁵⁴⁵ P3 and Fraunhofer IPT (9th April 2008): RFID – Spielweise für Technologiebegeisterte oder Schlüsseltechnologie zur Effizienzsteigerung? (RFID – Playground for technology freaks or key technology for the improvement of efficiency). <http://www.ipt.fraunhofer.de/press/StudieRFID.jsp>.

Figure 77: Typical frequencies use for RFID applications (RFID Report 2008)



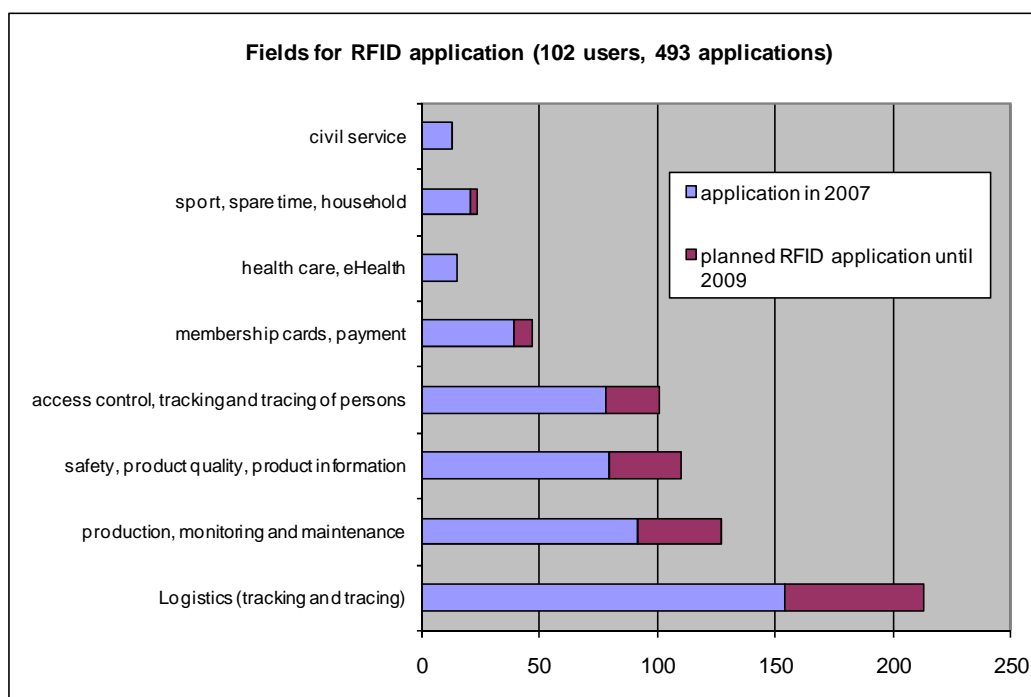
The following Table 173 provides an overview of the typical frequencies and their RFID applications.

Table 173: Typical RFID Frequencies and applications

Frequency	ISM Band (Typical RFID frequencies)	Coupling Range	Typical RFID application
Long wave (LF) 30 ... 300 kHz	9 kHz [sic] ... 135 kHz	0.5 m	Proximity identification of objects
Short wave (RF) 3 ... 30 MHz	6,78 MHz, 13,56 MHz, 27,125 MHz, 40,680 MHz [sic]	1.0 m	Access control
Decim. wave (UHF) 300 ... 3 GHz	433,920 MHz, 869 MHz, 915 MHz, 2,45 GHz [sic]	3.0 – 10 m	Tracking and tracing in store logistics
Micro wave > 3 GHz	5,8 GHz, 24,125 GHz	> 10 m	Vehicle positioning and identification

For 10% of the users, the RFID applications still have a prototype status, 33% are on the pilot test level and 57% use RFIDs during normal operation. Most companies which do use RFID use them in more than one application. The main fields of application are logistics (tracking and tracing of goods) as well as monitoring and maintenance in production. A growing segment is security and safety. Following Figure 78 provides an overview for the report's results.

Figure 78: Fields for RFID applications according to RFID-Report 2008



Similar results are provided by the second study [P3/IPT 2008] which was based on a survey including over 100 enterprises from logistics, machinery, automotive, aerospace and electronics. According to [P3/IPT 2008] the majority of existing RFID applications are very simple and have been realised in the field of logistics. More complex RFID applications along a wider internal process chain, e.g. for integrating external processes, are very seldom. This potential is not yet explored today due to a couple of technical and management related reasons.

One of the barriers for the implementation of RFID applications is the difficult integration in already existing business processes and IT infrastructures. The variety of existing technical standards and missing technical expertise create difficulties in establishing an effective solution. Both studies noticed that the enterprises who run RFID trials did not conducted technical feasibility studies prior to the projects. The companies underestimated the complexity of the RFID technology. As a result the efficiency gains were minimal and in 80% of the cases made the RFID application a negative experience for the enterprise. Also the costs for the trial phase are a major drawback. Finally the users criticise for running RFID systems the data security (73%) and the still accruing technical deficiencies (17%).

Despite these problems, RFIDs have a considerable potential to improve the efficiency processes in a wide area of applications. The following case studies provide respective application examples.

3.2.2.2 Case study: Shorter processing time and local positioning

Topic and technological concept

Depending on the particular transponder technology, RFIDs provide the option to be read simultaneously (anti-collision technology), which reduces the time for scanning each item. Large retailers such as METRO, TESCO or DELHAIZE have run tests with RFID-tags on their products and respective gates for easy checkout. In combination with inventory and procurement management systems, RFIDs provide an indirect energy trade-off by making processes more reliable and faster.

RFIDs however can also be used for faster locating objects, positioning and navigating machines. One example is the Local Positioning Radar developed by Symeo⁵⁴⁶. Symeo develops and applies contact-free sensor technologies to provide highly reliable distance measurement, positioning and navigation in real time with no wear & tear. The Local Positioning Radar (LPR) uses radio signals which are not susceptible to harsh ambient conditions. Symeo only use radio frequencies in the internationally freely available ISM-bands (Industrial, Scientific and Medical). Symeo equipment can be deployed indoor and outdoor under vibrations, extreme temperatures, dust and harsh weather conditions absolute positioning.

ICT application

The local positioning radar is utilising RFID technology. With a precise distance reading between a moving object and at least 3 fixed reference marks at known position, the dynamic position of this object can be determined. In the following, the fixed devices will be referred to as transponders (TP) and the moving unit is called base station (BS). With 2 antennas connected to the BS, the BS can compute both antenna positions independently in order to not only measure the position, but also the orientation (the angle σ) of the object in the chosen coordinates system.

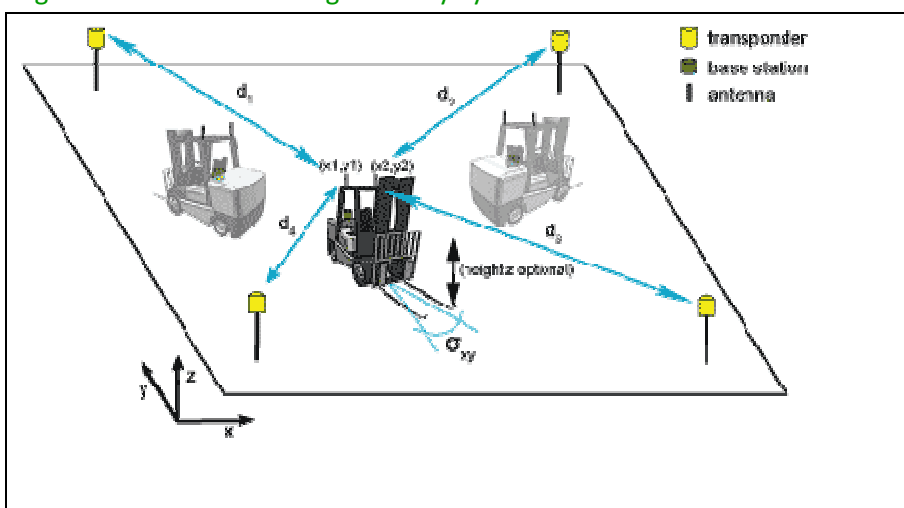
The LPR-A principle: Fixed TPs in known positions are used as reference marks for the positioning of a free ranging BS. The BS broadcasts a radio signal that is received, processed and echoed back to the BS by each TP without time delay. The echo is coded with the respective TP identification in order to allow the BS to separate each TP's answer. Thus, the BS can determine the round trip time-of-flight and the current distance to every TP independently. With at least 3 TPs within range, the BS position is well-defined.

The LPR-B principle: LPR-B devices can either be configured to act as TP or as BS. All units have their own ID-number, through which they can selectively communicate peer-to-peer with neighbouring devices. In order to measure distances between devices, a pico-seconds precise time synchronisation must be effective to determine the time-of-flight of signals sent.

⁵⁴⁶ Symeo: <http://www.symeo.com>

Communication between the devices takes place in the same ISM band that is also used for the distance measurement. Distance readings and other sensor data can be sent within the LPR-B network to any device within radio range. The position of moving objects can therefore be provided on-board the object or in a remote location without the need for wireless LAN occupation.

Figure 79: Local Positioning Radar by Symeo



There are various applications for this technology including:

- Local vehicle positioning
 - The position of vehicles to be monitored must be determined with an accuracy of a few cm only
 - Real time tracking is necessary to allow dynamic processes to immediately address deviations from the intended routing
 - Base-Station on vehicle computes the position, orientation and speed of the vehicle
 - Base-Station on vehicle provides this data in real-time for manual steering corrections or automatic navigation of an AGV (automatic guided vehicle)
- Pallet Logistics
 - Pallets are often kept in blocks on the floor
 - In order to retrieve products of a certain type or production date, the position of each single pallet must be monitored and stored in the warehouse management software
 - By continuously tracking pallets during every handling operation, each batch delivered is automatically precisely identified without (re-)scanning any pallet on the truck

- Container Logistics
 - On the given space of the terminals, logistics must ensure the efficient storage and retrieval of containers in a minimum of time
 - Exact positioning and tracking of all containers is therefore key
 - Continuous tracking of the carrier position

Other application ranges are:

- Paper and Cardboard Industry
- 3D Positioning of Coils and Slabs in the Metals Industry
- Crane positioning
- Anti-collision sensors for cranes

Energy Saving Potential

The energy saving potential is relative and (not generally) quantifiable and depends on actual application. It is determined by the time this technology saves to find an object at the right place and the distance this technology saves to transport an object at the shortest way possible. The energy saving potential is also offset by the additional energy consumption due to the use of RFID. However, these applications typically require very low power (e.g. 2W) and the net savings are estimated to still be significant.

3.2.2.3 Systemisation of the identified technical trends

The application of RFIDs for identification, tracking and tracing is not limited. The following applications of RFID technology in the supply chain are just generalised examples⁵⁴⁷:

- RFID in procurement and distribution
 - Automatic tracking and tracing of materials and goods (on-line localisation)
 - Identification of goods without visual contact (goods in a box)
 - Automatic sorting
 - Automatic booking of incoming single or bulk goods
 - Procurement data reconciliation
 - Real-time transmission of procurement data
 - Retour and End-of-Life logistics (tacking)

⁵⁴⁷ Plenty of examples are provided by the German internet portal „rfid-ready“ <http://www.rfid-ready.de> and the German Logistics Journal “Logistic Heute” <http://www.logistic-heute.de>

■ RFIDs in machinery and production:

- Automatic material and component tracking and tracing
- Automatic stock taking (inventory)
- Automatic production line and machine control (e.g. RFID on band conveyor)
- Machine to machine (M2M) communication (e.g. authentication)
- RFID with integrated sensors for quality control

The use of RFID technology allows furthermore combining tracking and tracing of objects (monitoring) with multi peer data transfer throughout the supply chain. The combination of simple RFID-tags with sensors (e.g. motion, temperature) provides basically a wireless sensor network (WSN) for data acquisition with many possible applications. Such microsystems would allow an assessment of the actual conditions within the supply chain (e.g. cooling of meat) which makes controlling processes smarter. The greater transparency also makes logistical processes more secure, time and cost efficient.

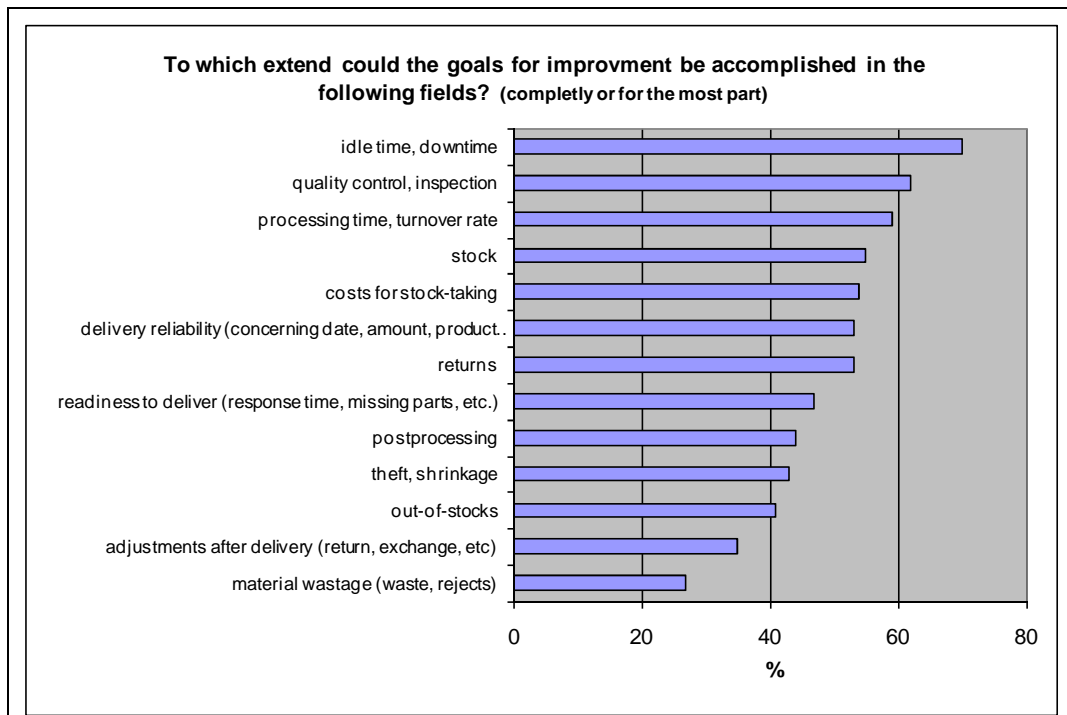
RFIDs also allow to store more information and if necessary to encrypt information on a product. A clear advantage of RFIDs in comparison to conventional bar-codes is not only their potential to store larger amounts of data but the rewriting of data (reuse) as well as the improved readability under harsh conditions such as dirt. The prevention of counterfeiting in the field of high value or quality critical products (e.g. pharmacy) can be enabled with RFID security markers to protect peripheral authenticity. RFID can than be embedded in peripherals/consumables to secure that only the correct consumables are used.⁵⁴⁸

3.2.2.4 Energy Saving Potential

- Existing applications and recent studies show that RFID technology can successfully improve the efficiency of processes. Following Figure 80 shows the result of the [VDI News 2008] RFID-Report regarding the improvements that have been realised by RFID solutions. The enterprises which successfully applied RFIDs could achieve remarkable results concerning the targets they had set for improving the efficiency of processes. The highest improvement rate with up to 70% was achieved in the reduction of processing time and the improvement of quality control.

⁵⁴⁸ Joseph Pearson: *Increasing Security in the Supply Chain with Electronic Security Markers*, Texas Instruments, White Paper, August 2006

Figure 80: RFID based efficiency gains by field of application (RFID-Report 2008)



In conclusion, RFID applications show a good potential to improve the time and cost efficiency, the quality of services and security of processes. It seems justified to assume that the shorter process times have a positive effect on the energy consumption, if we take the example of conventional stock taking, sorting and checkout of goods in a warehouse with a laser beam barcode scanner or with an antenna scanner gate for RFID labelled goods on a pallet. In the case of the laser beam barcode scanner each item has to be scanned individually which takes considerable amount of time (minutes) that has to be multiplied with the electricity consumption of the barcode scanner and the number of scanners applied for the process. A handheld barcode scanner consumes 1.0 to 7.0 Watts in use. In the case of the RFID solution (scanner gate) the anti-collision technology allows a very fast (seconds) scan of the whole pallet. In terms of energy consumption RFID transponder (UHF or RF) require generally very low power (e.g. 2 Watt). But the scanner gate is the factor of interest. The penetration of certain materials such as metal or water require considerably stronger signals (e.g. usually a RF transponder and amplified antenna signal) which increases power consumption.

It is noteworthy that the existing reports and studies on RFID applications do not mention energy consumption or savings. In our investigation we could not find any RFID case study which explicitly documented energy saving effects.

This situation leads to the conclusion that further studies on the topic of energy saving potentials of RFID applications are necessary.

3.2.2.5 Evaluation of Policy Options

Policy measures should focus on:

- Research and technical development (RTD): RFID technologies have reached a first stage of maturity which is indicated by the growing level of standardisation. However, RFID is still a very young technology with plenty of room for further technical development particularly in terms of materials and miniaturisation.
- The RTD should focus on new system standards which addresses compatibility (harmonisation) of single components. No harmonised frequency band for RFID applications that operate in the UHF band as in logistics exists. In Europe, a harmonised standard (EN 302 208) and a CEPT (European Conference of Postal and Telecommunications Administrations) recommendation (CEPT / ECC Recommendation 70-03 – Annex 11) exists, but implementation in the EU is still spotty.⁵⁴⁹
- The system robustness and performance needs to increase in order to realise encryption (security) and quality of service. Active RFID technology and application should be further developed. The environmental impacts of materials (e.g. silver for antenna) in mass applications should be considered.
- Information and guidelines: The successful introduction of RFID in business processes requires broad range of technical and economical expertise. RFID projects become more complex and particularly small and medium sizes enterprises (SME) are in need of external know how. The provision of technical information and best practice should be supported on Community and member state levels. Institutions which offer applied research to the industry should be promoted.

3.2.3. COMPUTER-AIDED DESIGN, SIMULATION AND VIRTUAL REALITY

3.2.3.1 Technical status and trends

The IT industry promotes a “four pillars” model which builds the basic information technology support structure in business or corporate environments. These four cornerstones are⁵⁵⁰:

- Product Lifecycle Management (PLM) to create and document the products being designed and the processes to manufacture them. PLM is the process of managing

⁵⁴⁹ RFID: The next to the Internet of Things, RFID – Outlook, Draft Paper, German Conference, Berlin, June 2007, online available at: http://www.rfid-outlook.pt/images/en/RFID%20Outlook%20paper_final%20version_240707.pdf

⁵⁵⁰ Mike Evans (2004): The PLM Debate. http://www.cambashi.com/research/plm_debate/plm_scm.htm

the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal.

- Customer Relationship Management (CRM) to identify customers and prospects for the enterprise, to provide a complete picture of contacts with them and enhance communications effectiveness.
- Supply Chain Management (SCM) to optimise the capital tied up in inventory and their unit costs. SCM encompasses inward and outward logistics systems that acquire materials to make products and ship finished goods to customers.
- Enterprise Resources Planning (ERP) to provide a single financial view, for as many departments as possible, of internal and external transactions that either add value or transform the status or location of a product, part or asset. ERP is often disguised as a new more fashionable acronym.

Of these four main pillars of corporate IT the Product Lifecycle Management (PLM) provides the specific IT tools that can support an energy conscious product and process designs. The following main PLM tools have to do with managing properties of a product through its development and use life from a business and engineering points of view.⁵⁵¹

- Product and Portfolio Management (PPM)
- Digital Product Development (DPD)
- Manufacturing Planning Management (MPM)
- Product Data Management (PDM)

Digital Product Development

Eco-design experts frequently argue that “approximately 80% of all product-related environmental impacts are determined during the product design phase”.⁵⁵² Considering environmental aspects in the design phase is therefore the most effective approach to improve energy efficiency of products, infrastructure, manufacturing processes, etc. This leads us to the actual topic of this subtask the **IT support tools for digital product development**. They are typically three tool categories and two application categories distinguished on the market:

- Computer-aided design (CAD) is the use of computer technology to aid in the design, development and optimisation of any kind of products, equipment, process or structures such as buildings. CAD is mainly used for detailed engineering of physical

⁵⁵¹ Please note that Product life cycle management (PLCM) has to do with the life of a product in the market with respect to business/commercial costs and sales measures

⁵⁵² EcoDesign Awareness Raising Campaign for Electrical and Electronics SMEs (EcoDesignARC). On behalf of the European Commission, DG Enterprise, the Fraunhofer IZM performed in 2005 - 2006 a project to raise awareness among SMEs regarding ecodesign issues. <http://www.ecodesignarc.info>

components through 2D vector base drafting systems to 3D solid and surface modellers. CAD enables designers to lay-out and develop work on screen, print it out and save it for future editing.

- Computer-aided manufacturing (CAM) is the use of computer-based software tools that assist engineers and machinists in manufacturing or prototyping product components. CAM is a programming tool that allows you to manufacture physical models using computer-aided design (CAD) programs. CAM creates real life versions of components designed within a software package.
- Computer-aided engineering (CAE) is the use of information technology for supporting engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis and repair. Software tools that have been developed for providing support to these activities are considered CAE tools. CAE tools are being used, for example, to analyse the robustness and performance of components and assemblies. It encompasses simulation, validation and optimisation of products and manufacturing tools. In the future, CAE systems will be major providers of information to help support design teams in decision making. In regard to information networks, CAE systems are individually considered a single node on a total information network and each node may interact with other nodes on the network.
- Computer simulation (CS), computer model or computational model is a computer program, or network of computers, that attempts to simulate an abstract model of a particular system. Computer simulations have become a useful part of mathematical modelling of many natural systems in physics (computational physics), chemistry and biology, human systems in economics, psychology, and social science and in the process of engineering new technology, to gain insight into the operation of those systems, or to observe their behaviour.
- Virtual reality (VR) is the use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment. VR applications immerse the user in a computer-generated environment that simulates reality through the use of interactive devices, which send and receive information and are worn as goggles, headsets, gloves, or body suits.⁵⁵³

Digital product design and simulation is state-of-the-art and most common in any research, design, and planning process.

The development and market of IT-tools for digital product design and simulation is a powerful business with an assumed strong influence on the energy efficiency of products and other infrastructures. According to ARC market research, the worldwide market for PLM software and services is expected to grow from 7.7 billion US \$ in 2006

⁵⁵³ Encyclopædia Britannica

to 14.5 billion US \$ in 2011.⁵⁵⁴ The automotive and aerospace industries are the dominating application sectors. The automotive sector (respective use of cars and trucks) contribute most considerably to the energy consumption. We will take the design of cars as an example in order to explain the impact of these IT-tools.

As a matter of fact, the value-added structure in the car industry is changing constantly towards automotive electronics. In 1985, the production value of automotive electronics was only 3% and the semiconductor share only 1% of the total value creation in an average medium size car. By 2005 already 22% of value creation was related to automotive electronic systems and 12% to semiconductors. By 2025 this share is assumed to increase to 30% and 20% respectively.⁵⁵⁵ Semiconductor-based electronics are mainly used as driver assistant systems and in the future for energy efficient and low carbon engine (motor) technology. The computer-aided design of these electronic systems will contribute directly to the fuel efficiency of modern cars and trucks.

Even though computer aided design is used, simulation is probably the only reliable mechanism for predicting and evaluating the performance of the system under varying loads and operating conditions without its physical existence. Furthermore, in the future, virtual reality with ambient intelligence will support new designs and the finding of alternatives.

3.2.3.2 Case Study: Purpose Oriented Simulation and Virtualisation

Simulation replaces new wind tunnel

Like its competitors, the BMW Sauber F1 Team's success depends heavily on the aerodynamic design of its racing cars. In 2006 and over a four-month period, the BMW Sauber F1 Team and Intel evaluated the performance of the Dual-Core Intel® Xeon® processor 5100 series to power the team's supercomputer cluster. They found that the Dual-Core Intel Xeon processor 5100 series performed three times faster than the existing server processor running FLUENT* — the team's CFD application. This allowed a better utilisation of the existing wind tunnel through faster tests. Based on these results, the team decided to invest in CFD, rather than an expensive second wind tunnel, to further improve its design process.⁵⁵⁶ We can only assume that the utilisation of the computer instead of a new wind tunnel is saving energy (e.g. resources for construction and use of the wind tunnel). As in most of such case studies specific data on energy savings are not available. But we conclude that CAD not only

⁵⁵⁴ VDI Nachrichten 11th April 2008

⁵⁵⁵ ElektronikPraxis Nr. 6-19. March 2008, p 36.

⁵⁵⁶ Intel: <http://www.developers.net/intelisdshowcase/view/2333>

Intel Helps BMW Sauber F1 Team Move Up The Starting Grid , Intel Corporation 2007 : http://www.intel.com/business/casestudies/BMW_Sauber_F1_case_study.pdf

improves the safety and reliability of products (e.g. a car), it has also a good potential for saving energy through the dematerialisation of objects and tests procedures.

Simulation of manufacturability

According to Automation World⁵⁵⁷ the importance of simulation in manufacturing has increased enormously in the last years. Due to improved simulation programs more and more companies use simulations as a basis for major business decisions. Simulating the manufacturability during the design process offers big potential cost and time savings compared to the traditional design processing [AutomationWorld]. Recent advances in factory simulation are pushing the technology beyond its core use for modelling automation to also provide help in areas ranging from training and product design to warehouse management and supply chain planning.

An example of a simulation tool is ABB's Expert Optimiser software which was selected by judges from Global Cement and Global Fuels magazines in early February. Cement is one of the most energy intensive industries, accounting for about 4% of global CO₂-emissions, and ABB's technology can reduce the energy consumption of cement plants by about 5%. Expert Optimiser allows cement plants to reduce energy consumption by optimising equipment used in the cement production such as mills, kilns and coolers, and implementing optimal schedules for the most efficient use of assets such as the grinding plant. Monitoring of energy consumption is carried out by the system in conjunction with ABB's Knowledge Manager Solution.

Earth Simulator

As an extreme example of what can be possibly simulated, the Earth Simulator has to be named. The Earth Simulator is a Japanese "supercomputer", used for scientific simulations such as earthquake forecast, weather and climate simulations. From 2002, when it was turned on, until 2004 it was the world's fastest computer with eight vector processors and the theoretical performance of 40 Tflop. It is situated in the Earth Simulator Centre in Kanazawaka-ku, Japan.

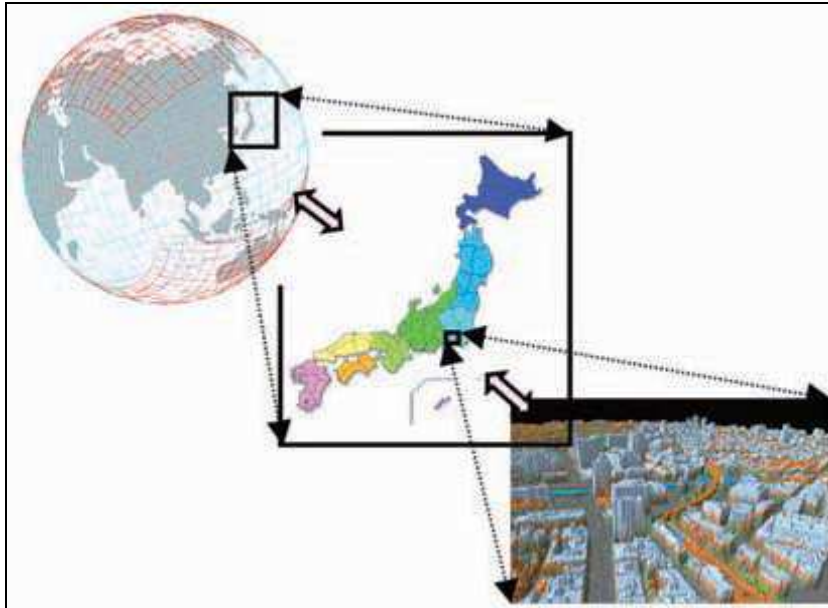
Different to other scientific simulations are mainly the extremely high resolutions which can be achieved while running global simulations (see Figure 81). With the Earth Simulator model-based as well as sensor-based (satellite input) simulations are possible [ESC⁵⁵⁸, Top500 Supercomputer Sites⁵⁵⁹]

⁵⁵⁷ AutomationWorld – Intelligence for the business of manufacturing automation: *Manufacturing by Computer Simulation*, <http://www.automationworld.com/view-907>

⁵⁵⁸ The Earth Simulator Center: <http://www.es.jamstec.go.jp/index.en.html>

⁵⁵⁹ Top500 Supercomputer Sites: <http://www.top500.org/system/details/5628>

Figure 81: Example of a global simulation running on the Earth Simulator [ESC]



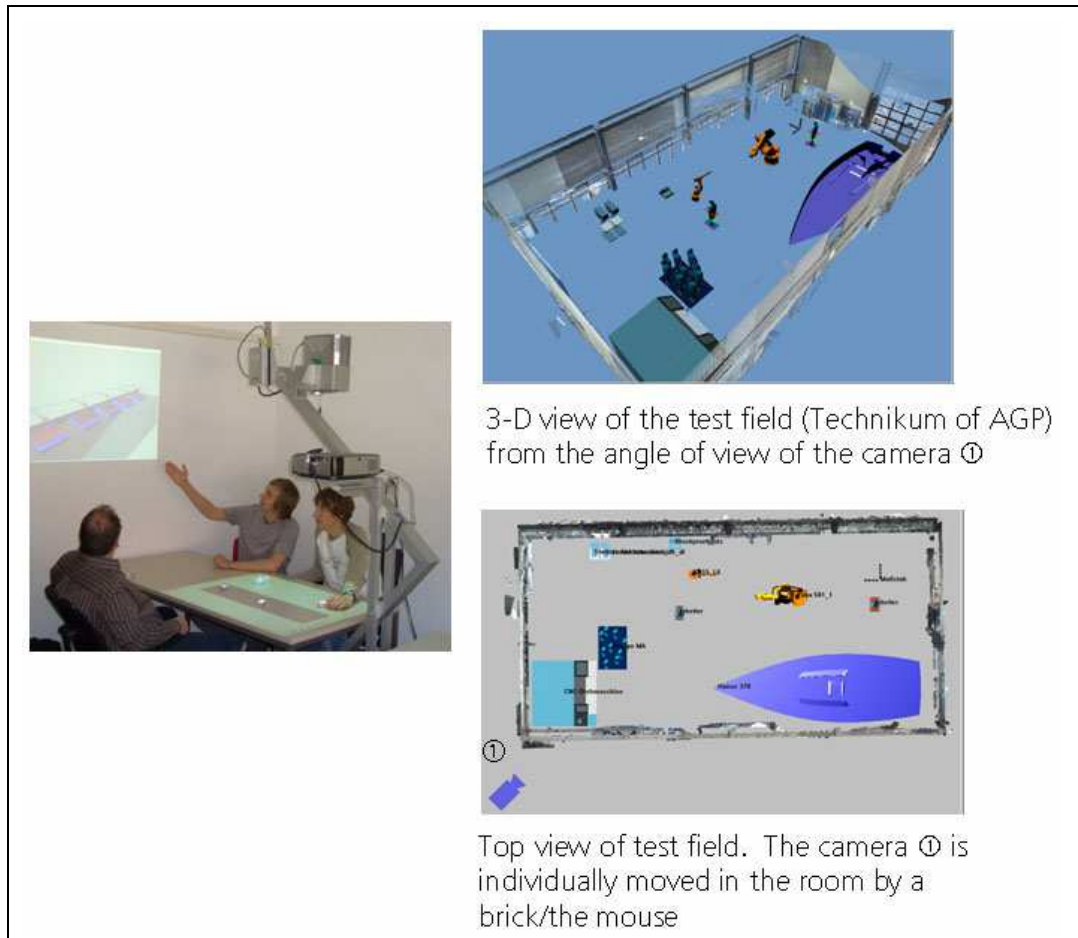
In principle, environmental research can be supported through such sophisticated IT equipment and software. Potential energy-efficiency gains are rather indirect as better knowledge about technical or ecological systems can help for a better understanding and improvement.

Planning table with integrated measuring data

The Fraunhofer IPA developed a planning table with integrated measurement data (Figure 82). This planning table can be used as input and visualisation surface. With a 3-D laser scanner the production resources can be measured and visualised. With this simulation, layout variants / alternatives can be evaluated immediately by the planning team [IPA⁵⁶⁰].

⁵⁶⁰ Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA) – Anwendungs-zentrum für Großstrukturen in der Produktionstechnik (AGP)
http://www.hro.ipa.fraunhofer.de/fhg/agp_en/Research_areas/organisation/planungstisch.jsp

Figure 82: planning table with integrated measuring data



Such real time visualisation applications become more important during the design process, not only by the planning team itself, but for customer presentations as early and comprehensible presentations may decide whether a product will be successful or not.

3.2.3.3 Systemisation of the identified technical trends and energy savings

Benefits

Digital product design and simulation tools support industry for creating better products and processes. Generally documented benefits of these tools include:

- Reduced time to market
- Improved product quality and performance
- Reduced prototyping costs
- Re-use of original data
- Process visualisation
- Savings through the complete integration of engineering workflows

Challenges

Cyon Research⁵⁶¹ however also names problems with current simulation tools, e.g. iterative and repetitive (design) processes are not supported very well by current software tools, often, each time you model a different possibility you have to start from scratches. Such problems together with abiding mistrust of digital solution by senior engineers would lead to the ongoing use of well-known/trusted, but manual and therefore time consuming methods, especially for complex products.

In an article by McLean and Leong on “The Role of Simulation in Strategic Manufacturing”⁵⁶², factors which inhibit the use of manufacturing simulation are discussed in more detail. One major point is the costs of the simulation technology. This includes e.g. licensing costs, salaries of manufacturing domain experts, simulation specialists, consultants, and support staff, training classes and translation of existing company data. Each company has to weight these costs against the risks of not using simulation. According to McLean and Leong, “if complex manufacturing systems are involved, simulation is probably the only reliable mechanism for predicting and evaluating the performance of the system under varying loads and operating conditions”. Other problems are data interface problems, missing modelling data, especially when a new manufacturing system is involved, and also problems with the interpretation and reliability of the simulation results [McLean, Leong].

Energy Saving Potential

It is not surprising that our study could not obtain quantitative data regarding possible energy savings related to digital product design. The energy related impact of products, infrastructure equipment, constructions, and manufacturing or logistical processes are highly diverse. The energy consumption is one of many aspects that can be determined and influenced with the help of CAD/CAM/CAE tools. Furthermore, computer-aided simulation is a useful means for dematerialisation. It is already state-of-the art to use computer simulations as much as possible for testing and evaluation of newly designed products. In the case of large and expensive investment goods such as cars, airplanes, ships but also bridges or manufacturing lines every aspect of the products design is tested with the help of computer models. Furthermore, computer simulations in combination with advanced sensor technology are also used for testing of “physical” models and prototypes. In the future, we expect a further merge of computer-aided design, simulation and sensor-based virtual reality in support of product development. The general assumption is justified, that such IT tools have a good potential to save energy in two ways:

⁵⁶¹ Cyon Research: „An Examination of UGS’ Repeatable Digital Validation (RDV) Framework”, 2005, <http://cyonresearch.com/LinkClick.aspx?fileticket=0Y1wIPatF%2FM%3D&tabid=84&mid=485>

⁵⁶² Charles McLean and Swee Leong: «The Role of Simulation in Strategic Manufacturing», Manufacturing Simulation and Modeling Group, National Institute of Standards and Technology, Gaithersburg, MD 20899, <http://www.mel.nist.gov/msidlibrary/doc/ifip5.pdf>

- Low energy products and systems through integrated eco-design
- Dematerialisation of prototypes and test equipment through simulation
- The policy options will focus on these two aspects in particular.

3.2.3.4 Policy measures

Supporting integrated eco-design

As mentioned before, the major part of the environmental performance including energy consumption is predefined during the product design process. **Eco-design** is an approach to an integrated design of a product with special consideration for the environmental impacts of the product during its whole lifecycle such as procurement, manufacture, use and disposal. Today's regular CAD tools for mechanical, electrical and electronics design do not take these factors into account. To give an example, in the field of electronics design for instance there are basically three global players (Cadence⁵⁶³, Mentor Graphics⁵⁶⁴, and Zuken⁵⁶⁵) and some SMEs which focus on special applications such as MEMS⁵⁶⁶ design. None of these software providers has an integrated eco-design tool although research seems to be ongoing.

Although energy related topics such as thermal management and electromagnetic compatibility are to some extent embedded in these design and simulations tools (or available as an adaptable add-on) there is to our knowledge no embedded or add-on eco-design tool available for complex mechanical, electrical or electronics designs. Product designers who want to integrate energy consumption/efficiency aspects directly into their designs and simulation mostly apply Life Cycle Assessment (LCA) methods/tools or eco-design checklists to the prototype or final products. Often manufacturers have their own software regarding the special environmental data demands of their products (e.g. for WEEE/RoHS compliance).

A guide to existing LCA and Eco-Design methodologies and tools including databases was compiled by Fraunhofer IZM within the EC DG Enterprise funded EcoDesignARC project⁵⁶⁷. A common approach to eco-design (reflecting this spectrum of impacts) is shown in Figure 83 below based on the lifecycle stages, environmental aspects and

⁵⁶³ Leading provider for IC and electronics system design <http://www.cadence.com>

⁵⁶⁴ Second largest provider for electronic design automation (EDA) including chip, board and electronics packaging design <http://www.mentor.com>

⁵⁶⁵ Third largest provider for electronic design automation (EDA) solutions as well as electronics specific computer aided engineering <http://www.zuken.com>

⁵⁶⁶ MEMS, Micro Electro Mechanical Systems

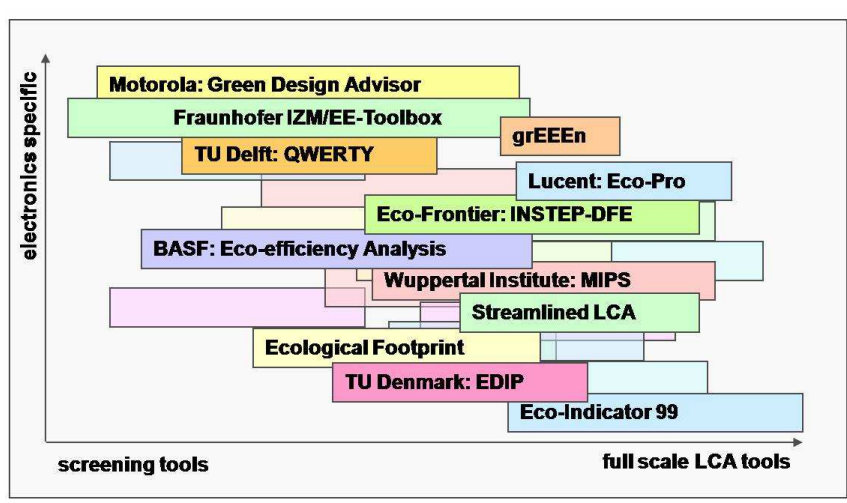
⁵⁶⁷ The EcoDesign Awareness Raising Campaign. <http://www.ecodesignarc.info>

tools that the Fraunhofer IZM/EE toolbox provides.⁵⁶⁸ Figure 84 shows an overview of existing eco-assessment and eco-design tools for electronics.

Figure 83: Eco-design criteria based on Fraunhofer IZM/EE toolbox

life cycle focus		environmental aspect		tool
raw materials acquisition	→	Energy	→	E _{RM} (energy raw materials)
↓				
manufacturing	→	Energy	→	E _{Mfg} (energy manufacturing)
	→	Toxicity	→	ProTox (process toxicity screening)
↓				
product	→	material contents / toxicity	→	TPI (Toxic Potential Indicator)
	→	material contents / emissions	→	TEP (Toxic Emissions Potential)
	→	Energy	→	E _{Use} (energy use phase)
↓				
end-of-life	→	Emissions	→	SES (Simple Emissions Screening)
	→	material contents / recycling feasibility	→	RPI (Recycling Potential Indicator)
	→	Energy	→	E _{Rec}

Figure 84: Electronics specific eco-assessment tools



Eco-design and life cycle assessment are closely linked. As in every design process (conception stage), decisions are based on assessments and existing information (e.g. technical performance parameters of components and materials, use conditions and requirements, costs etc.). The same applies to eco-design, for which environmental impacts based on LCAs are mostly considered. Integrated eco-design – that means the provision of environmentally relevant data on various levels of the conventional design

⁵⁶⁸ <http://www.izm.fraunhofer.de/EN/abteilungen/ee/service/izmeetoolbox/index.jsp>.

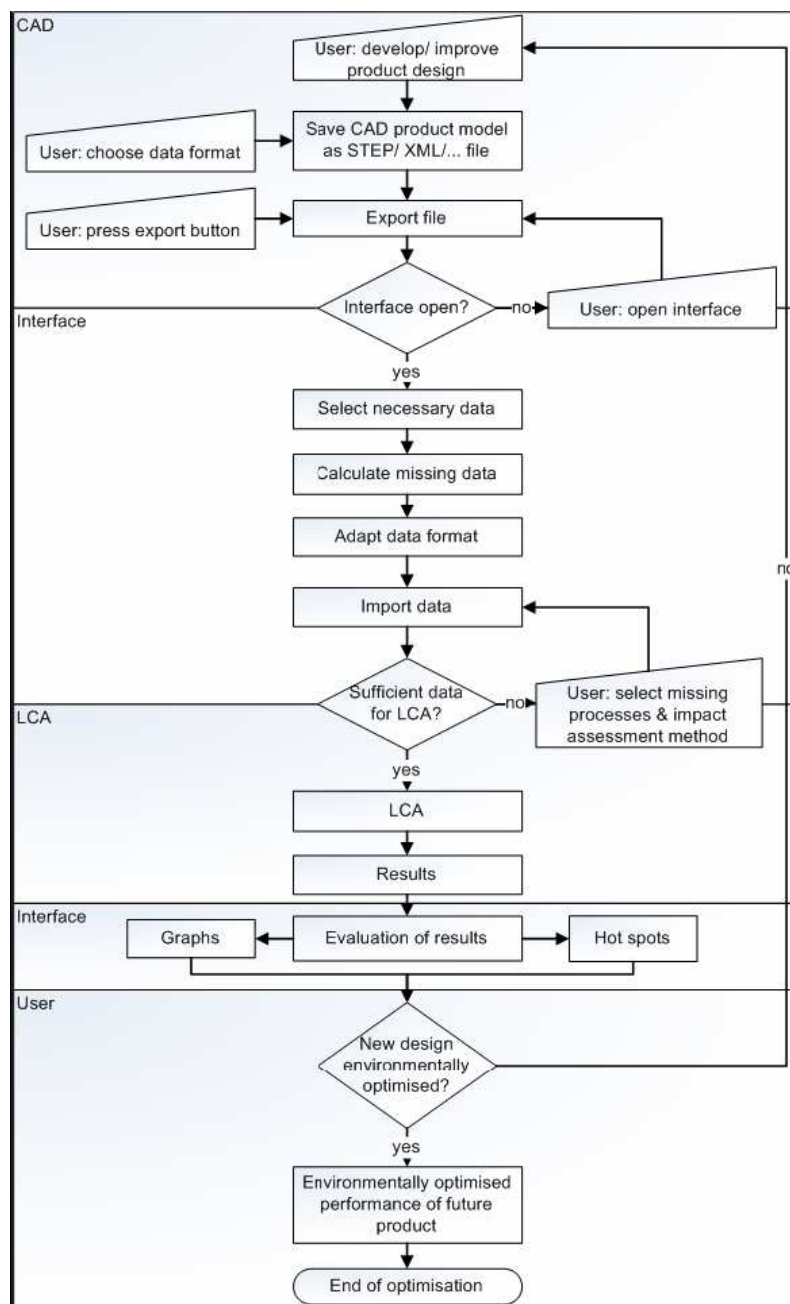
process – requires a simplified approach. A conventional design process (and IT tool) differentiates typically at three to four design levels:

- System design (system description and functional parameter analysis)
- Functional design (functional and structural conception)
- Physical design (selection of components and technology)
- Technical realisation (prototypes and testing, manufacturing processes, etc.)

On each level the product design team has to make decisions and check former decisions. But full LCAs are complex and very costly due to the need of many datasets. LCAs are also “post-product development” results and still difficult to integrate in existing CAD software. In other words, LCA tools are typically used for post product development; yet, the changes in environmental product performance are more difficult to achieve once a product is already implemented on the market. However, the same LCA tools can be used at the conception stage of a product if they are linked to a CAD tool, i.e. environmental assessment during product development can be carried out by linking computer aided design (CAD) and LCA software tools (see Figure 85): the product models (developed with the CAD software) can be transferred and used as inputs for carrying out an LCA. The LCA software tool’s database can be used to complete the process model describing the future product’s life cycle (if some data is missing).

The results of this life cycle assessment of a “virtual product” (product model) can then be adopted in product development. However such linkage is still difficult to realise because of no common data exchange format and this situation needs to be improved.

Figure 85: Linking a LCA software and a CAD tool⁵⁶⁹



⁵⁶⁹ Nora Marosky et al. *Challenges of Data Transfer between CAD- and LCA Software Tools* Technical University Berlin, Institute for Environmental Engineering, Department of Systems Environmental Engineering, Berlin, Germany 2007 <http://www.lcm2007.org/paper/50.pdf>

The policy options in that respect are mainly the support of research and technical development (RTD) as well as the provision of information and guidance.

The development of integrated eco-design tools is a task for the industry. It is not the task of European policy to develop eco-design tools, but European research funding can support the efforts of academia and industry to develop such tools. Policy measures should however focus and support:

- Harmonisation of a simplified eco-assessment methodology (see ongoing discussion to Eco-profile within the EuP)⁵⁷⁰,
- Harmonisation of eco-assessment data sets (see development of European Platform on Life Cycle Assessment)⁵⁷¹,
- Harmonisation of data compatibility (due to the fact that conventional CAD tools are licensed products with regular database/tool updates, most CAD software tools are not compatible),
- Harmonisation with existing and upcoming environmental legislation (see data requirements for REACH, EuP, ELV, etc.).

Future policy should generally promote the concept of energy efficiency as a benefit for the industry and the customers in particular. We expect that with the ongoing market awareness triggered by increasing oil prices and required by environmental legislation, energy efficiency will become an integral part of product design. Against that background we need harmonised conditions for useful product benchmarks in order to develop a green market.

3.2.4. CONCLUSIONS SUBTASK 3.2

RFID, CAD and virtual reality could create opportunities for saving time, energy and resources. Further studies, specifically on RFID applications focusing on energy savings are necessary. Research in the field of RFID should also focus on new system standards to address compatibility of components. As far as digital products are concerned, it is estimated that such practice is state of the art in most research, design and planning processes. However, today's regular CAD tools for mechanical, electrical and electronics design do not integrate eco (design (energy consumption/efficiency aspects) and an improvement of this situation is needed. Policy recommendations in that respect are mainly to support RTD, to support harmonisation of measures in

⁵⁷⁰ EuP Lot 5, Task 8: Televisions, online available at:

http://www.ecotelevision.org/docs/Lot%205_T8_Final_Report_06-08-2007.pdf

⁵⁷¹ The European Platform on Life Cycle Assessment (LCA) is a project by the Joint Research Centre, Institute for Environment and Sustainability (JRC-IES) and DG Environment. The aim of the project is to support business and public authorities with reference data and recommended methods on LCA to improve the credibility, acceptance and practice of LCA. <http://lca.jrc.ec.europa.eu/>

various areas (eco-assessment methodology, eco-assessment data, data compatibility and harmonisation of existing and upcoming environmental legislation (see data requirements for REACH, EuP, ELV, etc.)).

3.3. CONCLUSIONS TASK 3

The implementation of ICT applications in favour of dematerialisation in various areas could potentially provide energy savings through increased energy efficiency and reduction in other resource consumption (e.g. paper).

Findings showed that in an Eco-scenario, dematerialisation practices (mainly telework and videoconferencing) could provide energy savings equivalent to 0.8 % of EU 27 total electricity consumption (projected data for the year 2020) which is equivalent to CO₂ equivalent savings representing 0.6 % of EU 27 total CO₂ emissions.

As far as dematerialisation through RFID and CAD/virtual reality is concerned the current data available and the variety of application could not allow any extrapolation or quantification at EU level. However, some case studies indicate that opportunities for saving time, energy and resources could be created by these ICT applications.

The savings in the provided by the “dematerialisation” in this report need to be considered in perspective with the overall significance that dematerialisation could have in Europe if we had considered other dematerialisation practices (e.g. e-books), however in order to maintain solid scenarios subtask 2.1 focused on dematerialisation practices where enough reliable data on status and trends could be obtained.

It should also be reminded that the scenarios implied necessary assumptions and that as such the methodology lead to some limitations (i.e. not all potential gains/drawbacks could be analysed). However, the results still provide a good order of magnitude.

Action is needed in order to reach improvement through dematerialisation. Main recommendations include: improvement of statistical data, monitoring and information, financial incentives to promote the uptake of selected dematerialisation practices, support of public/private partnerships (e.g. in transport), information and guidelines and technology development, and support of the harmonisation of measures in various areas (eco-assessment methodology, eco-assessment data, data compatibility and harmonisation of existing and upcoming environmental legislation).

4. Conclusions

The study examined the impacts of Information and Communication Technologies (ICT) on the energy efficiency in Europe with a 2005-2020 outlook. It analysed not only the environmental footprint of the ICT sector itself, but also the effects of using ICT applications in support of higher energy efficiency and energy savings in other areas (building, industry, energy) (Task 2). It also explored the use of ICT applications in support of dematerialisation practices (Task 3).

Results from Task 1 showed that, despite the development of more energy efficient technologies and the miniaturisation of ICT devices, the ICT sector's overall electricity consumption will increase in the future due to the increase in the stock of ICT appliances, and network infrastructure (higher demand on servers and data storage capacity). In 2020, the ICT sector's overall electricity consumption is estimated to double compared to the 2005 situation, totalling 433 TWh (BAU scenario). In a more optimistic scenario (Eco-scenario), the ICT sector's electricity consumption is projected to be multiplied by 1.4, reaching 305 TWh. The ICT sector electricity footprint was converted into equivalent CO₂ emissions. The study found that in 2005, the ICT sector represented 99.0 Mt CO₂ eq. emissions. In a BAU scenario, this amount is estimated to reach 198.5 Mt CO₂ eq. for the year 2020 and 139.6 Mt CO₂ eq. in an Eco-scenario. However, it should be noted that the various assumptions used for the calculation of the equivalent CO₂ emissions lead to an overestimation of the CO₂ emissions related to the ICT sector: indeed, while assessing the environmental footprint of the ICT sector, business-lead initiatives to encourage the use of renewable energy to power ICT industries were not taken into account. Also the emission factor used to convert electricity consumption into equivalent CO₂ emissions was assumed to remain constant throughout the study. However, with the foreseen integration of a higher share of renewables in the European energy grid, this emission factor will probably decrease, leading to an overestimation of the ICT footprint in terms of CO₂ equivalent emissions. Nevertheless the estimations calculated still provide a good order of magnitude. Recommendation such as providing information to consumers to promote value efficiency and life cycle cost over purchase costs, the adoption of a European Green procurement scheme, the extension of the European Energy star labelling program or of the Energy label to other ICT devices (with priority to the most significant in terms of overall energy consumption), the development of financial incentives to foster green products, an increased support of innovation and R&D, etc. were formulated in order to reach the improvement targets set by the Eco-scenario.

Results from tasks 2 and 3 showed that the ICT sector footprint in terms of electricity consumption should however be put in perspective with the potential energy savings it could support through increase efficiency.

Indeed, the study indicates that applying ICT technologies in various areas: e.g. Buildings, Industrial equipment and automation, Energy grids and Dematerialisation, could support higher energy efficiency through the functionalities these technologies offer: e.g. monitoring of conditions (sensor), transmission of sensor data (network), processing, storage and display of data (computer/controller), modelling and simulation capabilities, driving and control of equipment (actuator).

In order to analyse and estimate the potential that ICT-based applications can provide, various scenarios were developed for each of these areas:

- **Baseline scenarios (reference scenarios):** mainly based on literature data, these scenarios do not take into account the increase in the use of ICT-based application. These scenarios are the reference against which to evaluate the alternative scenarios.
- **Business-as-Usual scenarios (BAU):** which assume continuity is maintained considering the current situation and trends (market, technology, policy, etc.)
- **Eco-scenarios:** which assume that there is a push (market based or technology based) for ICT-based energy efficient solutions (assuming higher improvement potential and/or higher uptake of energy efficient ICT-based technologies)

It may be surprising to have savings under BAU-scenarios. This is because ICT solutions provide energy and material savings compared to non-ICT applications. Therefore, the BAU-scenarios provide an estimation of the savings enabled considering the current trends and policy framework, compared to a baseline scenario where no further ICT-applications would be implemented.

The baseline scenarios were taken from literature (e.g. DG TREN statistics) where available (e.g. baseline scenario on transport of passengers). However, these statistics do not take into account the potential of ICT-based applications, therefore our need to build BAU-scenarios and to compare them against the baseline scenarios.

The Eco-scenarios provide savings which could be reached if ICT-applications were boosted by policy initiatives and business initiatives.

In the residential and service sector (buildings) ICT-based applications to control and monitor HVAC (Heating, Ventilation and Air Conditioning) systems and lighting systems as well as ICT-based efficient lighting technologies (e.g. LEDs) are expected to enable energy savings ranging from 453.6 TWh to 2115.5 TWh (in a BAU and Eco-scenario, respectively) for the year 2020 compared to the baseline scenario. The important savings in the buildings sector need to be considered in perspective with the overall significance of the building's sector in Europe which represents over half of the electricity consumption in Europe.

In the industry sector, increased energy efficiency based on ICT technology in motors was the main point of focus. In an Eco-scenario, the industrial sector could reduce the energy use of electrical drivers (motors) by almost 10% leading to a saving of 134.9 TWh (11.6 Mtoe) in 2020 compared to a baseline scenario.

In the Energy grid sector, the development of a Supply and Demand Management system (SDM) supported by ICT-applications could enable savings of primary energy equivalent to the quantity of primary energy needed to produce 148 TWh of electricity in 2020 compared to the baseline situation.

Considering the areas covered by the scenarios in Task 3 (e-government (focus on e-health and e-taxation), audio/video conferencing, e-work, dematerialisation of materials and services (e-ticketing, mobile ticketing, and digital music), **the increase in ICT-based on dematerialisation practices** (mainly dematerialisation of goods and transport substitution) could allow savings ranging from 23.3 and 33.4 TWh in 2020 (in a BAU and Eco-scenario respectively). These relatively “low” savings provided by the “dematerialisation” in this report need to be interpreted with care. This limited calculation does not reflect the potential of dematerialisation in Europe if all other dematerialisation practices (listed above) were included in the analysis. This, however, was not feasible mainly because of the unavailability of reliable data on status and trends of other dematerialisation practices. For example, in the case of dematerialisation through RFID and CAD/virtual reality, the lack of available data and the variety of existing applications prevented any extrapolation or quantification at EU level. However, some case studies indicate that opportunities for saving time, energy and resources could be created by ICT applications in this domain.

The results from Tasks 1, 2, and 3 can be put in perspective with the overall European electricity consumption in order to have a comparable dataset and evaluate the potential of higher energy efficiency enabled by ICT applications among the different sectors studied (Figure 86 and Table 174).

This shows that the Eco-scenario for buildings leads to significant savings (mostly in the residential sector) and that the building sector shows the highest potential of improvement through ICT-based applications, followed by the Energy grid sector and the industrial and automation sector (efficient motors). Energy efficiency through dematerialisation seems less significant, however, the savings calculated by this study do not cover all aspects of dematerialisation and further savings should be observed in reality.

Figure 86: ICT electricity use and ICT-based energy saving potential in other sectors

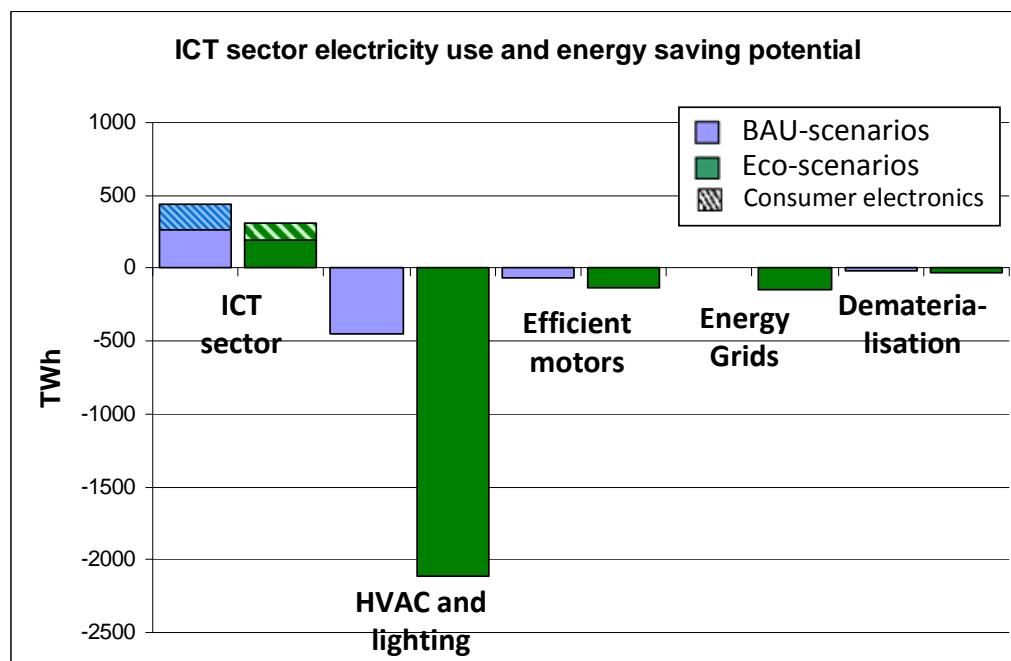


Table 174: Summary of estimated ICT energy use and energy saving potential (2020)

Source	EU 27	TWh	Share of total projected EU 27 electricity use (%)	Mt CO ₂	Share of total EU 27 CO ₂ eq. emissions (1990 level) (%)
Task 1	CALCULATED ENERGY USE ICT sector (use phase) in 2020				
	BAU-scenario - Consumer Electronics included in the ICT sector	433.1	10.9%	198.5	3.6%
	Eco-scenario Consumer Electronics included in the ICT sector	304.7	7.7%	139.6	2.5%
	BAU-scenario without Consumer Electronics	259.1	6.5%	118.7	2.1%
	Eco-scenario without Consumer Electronics	195.8	4.9%	89.7	1.6%
Task 2 - Subtask 2.1	CALCULATED SAVING POTENTIAL (2020)				
	HVAC + Lighting Residential BAU	346.6	8.7%	51.7	0.9%
	HVAC + Lighting Service BAU	107.0	2.7%	15.5	0.3%
	HVAC + Lighting Residential Eco	1,766.6	44.4%	240.5	4.3%
	HVAC + Lighting Service Eco	348.9	8.8%	47.2	0.8%
Task 2 - Subtask 2.2	Efficient motors BAU	67.5	1.7%	30.9	0.6%
	Efficient motors Eco	134.9	3.4%	61.8	1.1%
Task 2 - Subtask 2.3	Primary energy savings through load shifting (Eco)	433.0	not relevant (primary energy savings)	-	0.3%
	Equivalent electricity that could be generated with 433 TWh of primary energy (calculated based on the EcoReport factor: 1 MWh electricity = 10500 MJ= 0.251 toe) (Eco)	148.0	3.7%	17.4	0.3%
Task 3 - Subtask 3.1	Dematerialisation BAU	23.3	0.6%	17.8	0.3%
	Dematerialisation Eco	33.4	0.8%	26.5	0.5%
Task 3 - Subtask 3.2	Management and process support	No quantified savings	-	-	-
All tasks	Total estimated savings (BAU)	544.4	13.7%	115.9	2.1%
	Total estimated savings (Eco)	2,431.8	61.1%	393.4	7.1%
	Total net Savings (BAU) Consumer Electronics included in the ICT sector	111.3	2.8%	-82.6	-1.5%
	Total net savings (Eco) Consumer Electronics included in the ICT sector	2,127.1	53.5%	253.8	4.6%
	Total net Savings (BAU) without Consumer Electronics	285.3	7.2%	-2.8	-0.1%
	Total net savings (Eco) without Consumer Electronics	2,236.0	56.2%	303.7	5.5%

The study shows that the overall net energy savings⁵⁷² enabled by ICT-based technologies are positive both in the BAU and Eco scenario (Table 174).

When compared to the EU 27 total electricity consumption⁵⁷³ projected for the year 2020, the net energy savings can amount to 2.8 % (111.3 TWh) of EU-27 total electricity consumption in the BAU scenario and 53.4 % (2,127 TWh) in the Eco-scenario.

In order to provide an order of magnitude for putting the results in perspective with the EU policy target on primary energy reduction, the net savings can be expressed in terms of equivalent primary energy required to produce the same amount of TWh of electricity. Such equivalence (the primary energy required to produce 111.3 TWh and 2,127 TWh of electricity is 27.9 Mtoe and 533.9 Mtoe respectively⁵⁷⁴) indicates that, when compared to the total EU-27 projected primary energy consumption, the net savings could represent between 1.7 % (BAU) and 32.5 % (Eco).

Taking out the consumer electronics from the total electricity consumption represented by the ICT sector (i.e. TVs, mobile devices, audio systems, VHS/DVD equipment, and set-top boxes, which are assumed to play a less important role in supporting the enabling effects of ICT technologies) the net energy savings were estimated to 285.3 TWh in a BAU-scenario and 2,246.6 TWh in an Eco-scenario.

However, these numbers should be interpreted with care as they only suggest an order of magnitude (i.e. all the energy savings do not refer to the electricity savings).

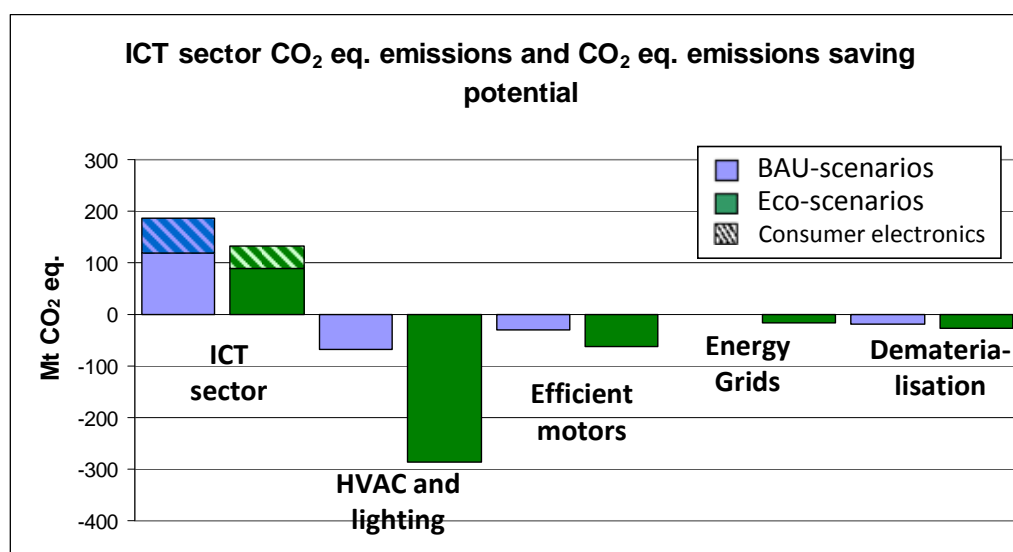
In terms of CO₂ eq. emissions, the study found that the net savings were only positive in the Eco-scenario and amounted to 4.6 % of EU-27 CO₂ eq. emission level of 1990.

⁵⁷² i.e. savings enabled by ICT applications in other sectors to which is subtracted the energy consumption of the ICT sector itself

⁵⁷³ This comparison is realised only to provide an order of magnitude, however, it should be noted that the energy savings enabled by ICT do not only refer to electricity savings (e.g. HVAC systems in buildings are based on different types of energy : oil, gas, etc).

⁵⁷⁴ Such equivalence was calculated using the conversion factors from the EcoReport tool which is the official life cycle analysis tool developed in the framework of the Eco-Design Directive 2005/32/EC i.e. 1MWh electricity = 10,500 MJ primary energy = 0.251 toe primary energy

Figure 87: ICT sector CO₂ eq. emissions and CO₂ eq. emissions saving potential



To conclude, the study shows that in the Eco-scenario, the savings could represent over 7 times the ICT sector's direct impacts in terms of energy and about 3 times in terms of CO₂ emissions.

In the BAU scenario, the savings were found to be slightly higher than ICT sector's footprint in terms of energy consumption (savings represent 1.26 times the ICT sector electricity consumption). However, in terms of CO₂ eq. emissions, ICT sector's emissions were estimated to be higher than the CO₂ savings (1.7 times higher).

This illustrates that key actions are needed to achieve the Eco-scenario. They are suggested in sector-specific recommendations for each of the three ICT effects on energy efficiency analysed in the study. The recommendations provided are covering the following aspects:

- Development of standardised methods to measure environmental performance of ICT based products and services
- Improvement and monitoring of statistical data to make efficiency and effectiveness a reality
- Development of appropriate incentives to encourage the take up of energy efficient technologies and practices
- Promotion of public-private partnerships in energy efficiency
- Provide Information and guidelines
- Development of internet connectivity to facilitate ICT-based solutions
- Identification of R&D needed in ICT and further support for R&D together with Innovation actions
- Development of open standards and interoperability

ANNEXES

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Annexe 1: E-health

Information and Communication Technologies can have a massive impact on all aspects of healthcare, from delivering the information people need to lead a healthy lifestyle to providing new tools to design tomorrow's medicines; from making healthcare systems more efficient and responsive to providing 'in the home' and mobile healthcare technologies. However, the health sector is very information intensive, and advanced ICTs can make healthcare systems more cost-effective, allowing more funds to be spent on healthcare, and less on administering it. "e-Health" is therefore emerging as an important new global industry. In the *e-Health Action Plan, 2004*, the European Commission defines e-health as "e-Health tools and solutions include products, systems and services that go beyond simply Internet-based applications. They include tools for health authorities and professionals as well as personalised health systems for patients and citizens. Examples include communicable systems, health portals, and many other information and communication technology-based tools assisting prevention, diagnosis, treatment, health monitoring, and lifestyle management".⁵⁷⁵ E-health therefore includes several concepts

- Telemedicine

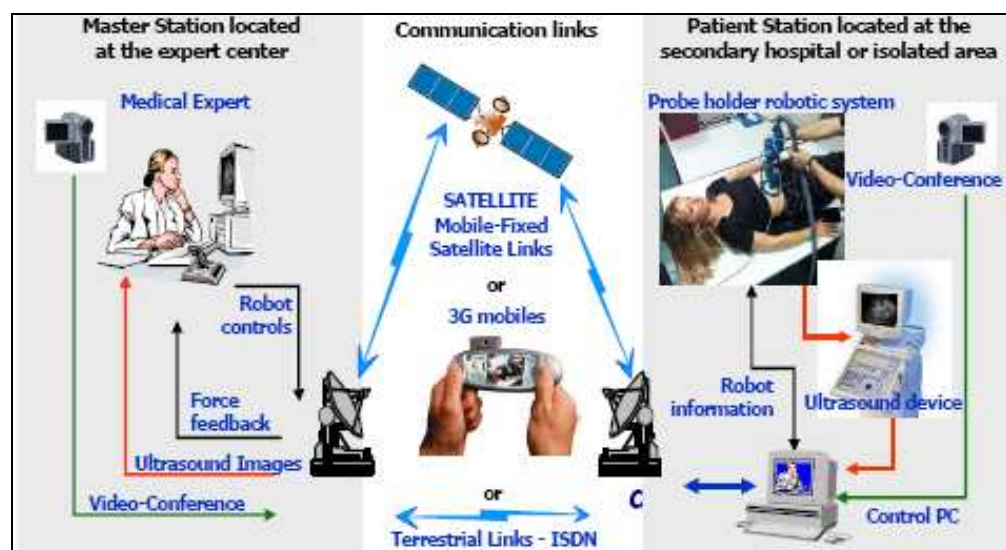
Telemedicine refers only to the provision of clinical services via telecommunications-diagnosing, treating or following up with a patient at a distance while the term e-health can refer to clinical and non-clinical services such as medical education, administration, and research. European Commission's health care telematics programme defines telemedicine as "rapid access to shared and remote medical expertise by means of telecommunications and information technologies, no matter where the patient or relevant information is located".

For instance, one common application of telemedicine is called "store and forward". It is used for transferring digital images from one location to another. A digital image is taken using a digital camera, ('stored') and then sent ('forwarded') by computer to another location. This is typically used for non-emergent situations, when a diagnosis or consultation may be made in the next 24 - 48 hours and sent back. The image may be transferred within a building, between two buildings in the same city, or from one location to another anywhere in the world. Teleradiology, the sending of x-rays, Computed tomography scans (CT scans), or magnetic resonance imaging (MRIs) is the most common application of telemedicine in use today and many radiologists are installing appropriate computer technology in their homes, so they can have images sent directly to them for diagnosis, instead of making an off-hours trip to a hospital or clinic.

⁵⁷⁵ European Commission, E-Health Action plan, 2004
http://eur-lex.europa.eu/LexUriServ/site/en/com/2004/com2004_0356en01.pdf

Another common application of telemedicine is remote consultation through the use of video conferencing equipment, for a “face-to-face” consultation. The patient and sometimes their provider, or more commonly a nurse practitioner or telemedicine coordinator (or any combination of the three), are at the originating site. The specialist is at the referral site, most often at an urban medical centre. There are many configurations of an interactive consultation, but most typically it is from an urban-to-rural location. It means that the patient does not have to travel to an urban area to see a specialist, and in many cases, provides access to medical expertise when none has been available previously. Almost all specialties of medicine have been found to be conducive to this kind of consultation, including psychiatry, internal medicine, rehabilitation, cardiology, paediatrics, obstetrics and gynaecology, and neurology. There are also many peripheral devices which can be attached to computers which can aid in an interactive examination. For instance, an otoscope allows a physician to 'see' inside a patient's ear; a stethoscope allows the physician to hear the patient's heartbeat. Recently (2005) tele-echography has been made available, allowing a specialist to perform an echography without being near the patient through the use of a portable tele-operated device. It includes an expert station from which the expert (a sonographer) orientates a fictive probe. These movements are reproduced at patient station, several miles away, on a real probe held by a robot and positioned on the patient by a paramedic. An audio/video link between the two sites allows communication between the expert, the assistant and the patient (Figure 88). These applications can be useful for populations located in remote areas (e.g. islands) where doctors and experts are not always available however they are not transposable to dense urban areas which are well equipped in terms of medical structures.

Figure 88: mOBile Tele-Echography using an ultra Light rOBot project (OTELO)



- Remote monitoring

ICT can be applied in the health sector to assist continuous monitoring of vital signs, such as blood pressure, blood glucose, body temperature, etc., in real time. For example, technologies such as a wristband blood-pressure monitoring device can check vital signs such as heart rate. Blood-pressure readings, for example, are gathered from one or more sensors via a Bluetooth short-range radio connection⁵⁷⁶. Once transmitted, secure access ensures only authorised medical personnel see the patient's data. If an unusual reading comes through, either a reminder can be sent to the patient to take his or her medication or a new prescription can be made, depending on the doctor's diagnosis (Figure 89).

Figure 89: Health monitoring devices⁵⁷⁷



- Health data management

ICTs can allow replacing paperwork with smartcards, in which medical history of patients, medical insurance information and other data can be stored.

In many Member States, ICT-based technologies allow medical costs being reimbursed automatically through the use of such cards, making the need for paper forms obsolete. Some examples are:

In Germany for medical costs every member of the compulsory health insurance fund is obliged to use a chip-card for medical attendances. No citizen has to fill in any forms or papers. Belgium has been one of the first countries to introduce a smart social insurance card (SIS card). This card enables direct settlement of certain medical costs⁵⁷⁸. Costs for medical treatment and medicine in Austria are usually covered by obligatory health insurance and there is usually no need for citizens to ask for any reimbursement. In Italy citizens do not have to request for reimbursement of medical costs. The National Health Service (SSN) is administered

⁵⁷⁶ Short-range radio link used to exchange information, enabling wireless connectivity between mobile phones, mobile PCs, handheld computers and other peripherals

⁵⁷⁷ IBM, <http://www.zurich.ibm.com/csc/mobile/index.html>

⁵⁷⁸ <http://riziv.fgov.be/>

by the Regions and is free at the point of delivery. The reimbursement for medical costs is direct from Ministry of Health to Regions. There is no need for Lithuanian residents to ask for any reimbursement. Costs for some medicines are covered by mandatory health insurance and Lithuanian residents pay only that part of the cost for such medicine which is not reimbursed. In Norway treatment is free of charge for the patient and therefore doesn't need to be reimbursed. The national insurance administration reimburses the hospitals directly after the patients have been treated.

At the European level, the European health insurance card is already available since June 2004 when new regulations simplified procedures so that the electronic health insurance card would replace all the paper forms used while on a temporary stay. Pilot activities and implementations have already started. Through Directorate General Social Affairs and Employment of the European Commission, activities are underway to survey the number of electronic health insurance cards available throughout Europe. Such cards could feature added functionalities, such as medical emergency data and secure access to personal health information. The next 2008 target would be the creation of a European electronic health card enabling identification of the patients and availability of their electronic health record. Slovenia is at the forefront among new member states in this area⁵⁷⁹.

- Health information and online services

Online health services are also part of e-health. It is one of the public sectors investigated in the i2010 action plan mentioned above. In the 2007 Benchmarking report of the supply of online public service⁵⁸⁰ (see Table 114), the average level of sophistication of the online health related services is less than 43 % in EU-27. This is equivalent to level 2 (see Figure 52) and could still be improved (Table 175).

⁵⁷⁹ http://www.zzs.si/kzz/ang/hic_idx.htm

⁵⁸⁰ Cap Gemini. *The User Challenge: Benchmarking The Supply Of Online Public Services*. 7th Measurement September 2007. For the European Commission, Directorate General for Information Society and Media. http://ec.europa.eu/information_society/eeurope/i2010/docs/benchmarking/egov_benchmark_2007.pdf

Figure 90: Full availability online of Health related services⁵⁸¹

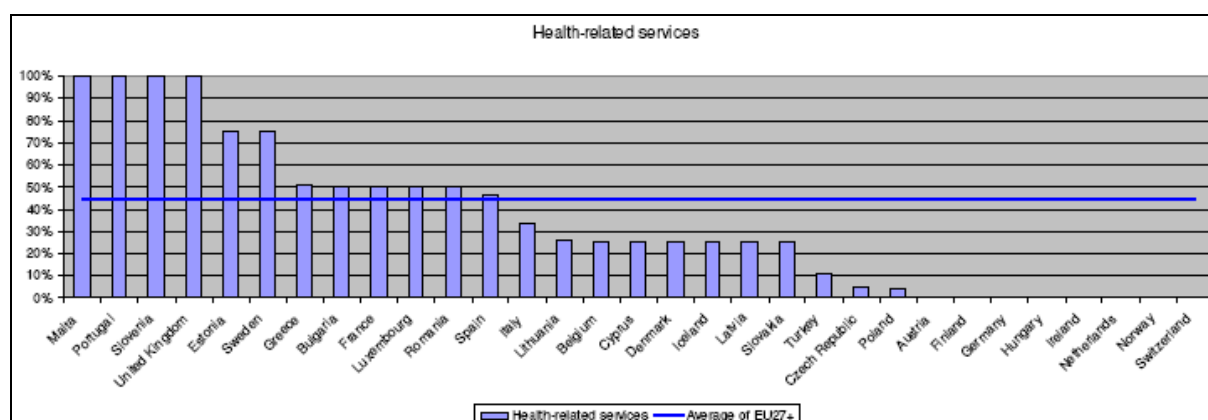


Table 175: Definition of the level of sophistication of online health related activities⁵⁸²

Stage 0	The service provider or the administrative responsible level does not have a publicly accessible website or the publicly accessible website managed by the service provider or by the administrative responsible level does not qualify for any of the criteria for the stages 1 to 4.
Stage 1	The information necessary to start the procedure to obtain an appointment at a hospital is available on a publicly accessible website managed by the service provider or by the administrative responsible level.
Stage 2	The publicly accessible website managed by the service provider or by the administrative responsible level offers the possibility to obtain the paper form to start the procedure to obtain an appointment at a hospital in a non-electronic way.
Stage 3	The publicly accessible website managed by the service provider or by the administrative responsible level offers the possibility of an electronic intake with an official electronic form to start the procedure to obtain an appointment at a hospital.
Stage 4a	The service provider offers the possibility to completely treat the demand of an appointment via the website. Case handling, decision and delivery of a standard procedure to obtain an appointment at a hospital can be treated via the web. No other formal procedure is necessary for the applicant via "paperwork"
Stage 4b	An appointment in a hospital can be made by an intermediary, a GP, via an electronic network that links him with the hospital.
Stage 5	NOT APPLICABLE

Four indicators are available to assess the current situation of e-health in Europe from the *Eurostat 2005 Community Survey on ICT Usage and e-Commerce in Households*: the use of the internet in the last three months for private purposes for:

⁵⁸¹ Cap Gemini. *The User Challenge : Benchmarking The SupplyOf Online Public Services*. 7th Measurement September 2007. For the European Commission, Directorate General for Information Society and Media. http://ec.europa.eu/information_society/eeurope/i2010/docs/benchmarking/egov_benchmark_2007.pdf

⁵⁸² Cap Gemini. *The User Challenge : Benchmarking The SupplyOf Online Public Services*. 7th Measurement September 2007. For the European Commission, Directorate General for Information Society and Media. http://ec.europa.eu/information_society/eeurope/i2010/docs/benchmarking/egov_benchmark_2007.pdf

- seeking health-related information, e.g. injury, disease, nutrition, improving health, etc.
- making an appointment online with a practitioner
- requesting a prescription online from a practitioner (Figure 91)
- seeking medical advice online from a practitioner.

Regarding these four health-related activities, seeking health-related information is the one most widespread. The other three health-related activities can be considered as being still at their beginning (Table 176).

Table 176: Percentage of population who has used the internet for Health related online activities in Europe (2005)⁵⁸³

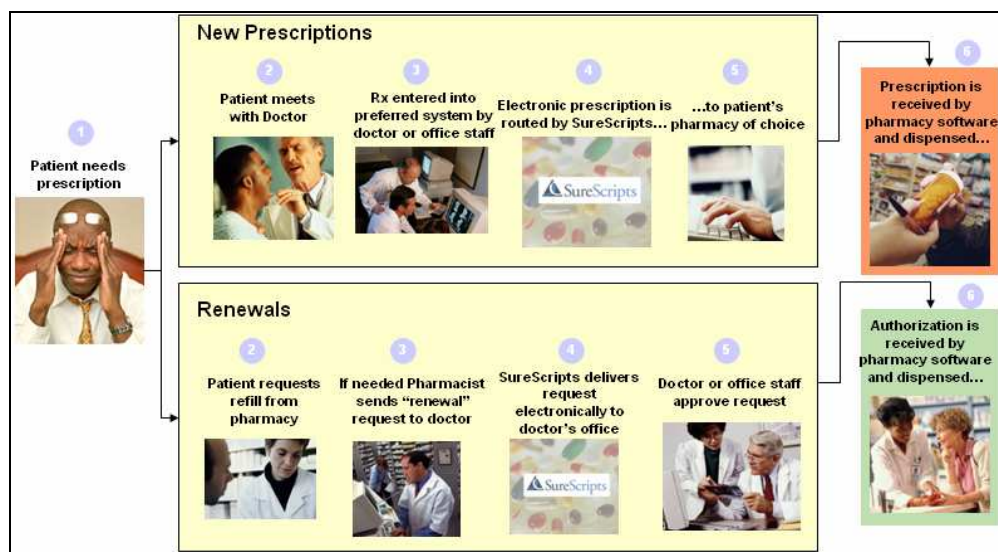
	Country	Seeking health information	Appointment with a practitioner	Requesting a prescription	Seeking medical advice
EU 25	European Union (25 countries)	15.1	0.5	0.4	1.7
EU 15	European Union (15 countries)	17.0	0.6	0.4	2.0
BE	Belgium	19.1	:	:	:
CZ	Czech Republic	3.5	0.4	:	0.3
DK	Denmark	23.8	1.7	0.7	2.5
DE	Germany	:	:	:	:
EE	Estonia	16.4	8.4	4.9	10.9
GR	Greece	2.2	0.1	0.0	0.4
ES	Spain	12.8	0.4	0.1	2.4
FR	France	:	:	:	:
IE	Ireland	10.5	0.1	0.1	0.6
IT	Italy	8.7	0.4	0.2	1.6
CY	Cyprus	8.0	0.1	0.2	0.3
LV	Latvia	7.4	0.1	0.1	0.5
LT	Lithuania	8.5	0.3	0.0	1.2
LU	Luxembourg	41.0	0.7	0.8	1.6
HU	Hungary	9.6	0.4	0.2	0.8
MT	Malta	:	:	:	:
NL	Netherlands	:	:	:	:
AT	Austria	16.0	0.8	0.3	0.5
PL	Poland	7.1	0.1	0.1	0.4
PT	Portugal	10.0	:	:	0.4
SI	Slovenia	15.4	:	0.0	:
SK	Slovakia	9.1	0.2	0.0	0.0
FI	Finland	39.0	3.4	:	2.7
SE	Sweden	23.2	0.0	1.0	4.2
UK	United Kingdom	25.5	:	:	4.4
BG	Bulgaria	:	:	:	:
RO	Romania	:	:	:	:

(:): Data not available

The application of ICT in the health sector also enable to develop more powerful solutions, such as the use of supercomputers and Grids to help discover new medicines. However, in the perspective of improving the energy efficiency of the health sector through dematerialisation, this issue will not be covered by the present study.

⁵⁸³ Empirica. *Benchmarking in a Policy Perspective Report No. 4 Public Services*. (2006) http://ec.europa.eu/information_society/eeurope/i2010/docs/studies/wp4_report_online_public_services.doc

Figure 91: e-prescription process⁵⁸⁴



⁵⁸⁴ <http://www.emrworld.net/emr-research/articles/eprescribing.ppt#263,4>

Annexe 2: Complementary data on audio conferencing at BT

Table 177: Travelled distance and equivalent CO₂ emissions avoided

Mode of travel	Number of Responses	Mean travelled distance avoided (km)	Total travelled distance avoided (km)	Total CO ₂ Avoided (kg) ⁵⁸⁵	CO ₂ Avoided per Trip (kg)
All Modes*	225	398	89,422	15,660	70
All Modes Excluding Air*	204	229	46,565	9,242	45
Petrol Car	69	233	16,056	3,243	47
Diesel Car	37	219	8,118	1,513	41
Van/LGV	18	171	3,066	619	34
Train	79	233	18,400	3,716	47
Air	21	2041	42,857	6,418	306
Taxi	15	18	264	53	4
Tram/Tube	13	37	488	98	8
Other(All Other)	16	11	174	-	-

* This is the number of unique respondents to the question, reflecting the fact that some people use more than one mode.

Table 178: Financial value of avoided meetings resulting from conferencing

	Value per meeting (€)	Total value for BT (€)
Time	167	143,652,384
Travel	206	152,861,654
Overnights	42	35,913,096
Total Value	415	332,413,210

⁵⁸⁵ Based on the updated CO₂ emissions figures provided in DEFRA, *Company Reporting on Greenhouse Gas Emissions*, Annex, 2005. These are 0.325kg per passenger mile for petrol cars (average of consumption for medium and large engine sizes) and van/LGV, 0.3kg per passenger mile for diesel cars, 0.064kg per passenger mile for rail, 0.241kg per passenger mile for air. These conversion factors have been updated since and are available at :

<http://www.defra.gov.uk/environment/business/envrp/pdf/conversion-factors.pdf>

Annexe 3: Complementary data for the DFID video-conferencing case study

Table 179: Video conferencing use

Frequency of use	Number of responses	Percentage
High – more than twice a week, on average	32	14.1%
Medium – one or two times a week, on average	98	41.5%
Low – only use irregularly	92	38.9%
Never use	4	1.7%
Total	226	

Table 180: Details of avoided trips

Type of trip	Number of respondents saying definitely	Percentage	Number of respondents saying highly likely	Percentage
Trip between East Kilbride and London	10	30%	21	39%
Other trip within the UK	2	6%	2	4%
Trip between the UK and Europe (or vice versa)	2	6%	4	7%
Trip between the UK and Africa (North, East or West) (or vice versa)	3	9%	4	7%
Trip between the UK and Africa (South) (or vice versa)	2	6%	3	6%
Trip between the UK and North America (or vice versa)	1	3%	1	2%
Travel between the UK and the Caribbean/Central America (or vice versa)	2	6%	2	4%
Travel between the UK and South Asia (or vice versa)	0	0%	0	0%
Travel between the UK and East/South East Asia (or vice versa)	4	12%	5	9%
Other long haul travel from/to the UK	1	3%	2	4%
Plane travel within a DFID region (outside Europe)	3	9%	7	13%
Other travel	2	6%	2	4%
My last conference call didn't avoid travel	1	3%	1	2%
Total responses	33		54	

Table 181: Distance avoided by last conference call, by mode of travel and type of travel

	Respondents definitely avoiding travel	Assumed distance (miles)	Total distance (miles)	Total distance (km)
Long Haul Travel - Air				
Trip between the UK and Africa (North, East or West)	3	8,492	25,476	41,000
Trip between the UK and Africa (South)	2	11,280	22,560	36,307
Trip between the UK and North America (or vv)	1	6,916	6,916	11,130
Travel between the UK and the Caribbean/Central America	2	8,420	16,840	27,101
Travel between the UK and East/South East Asia	4	11,838	47,352	76,206
Other long haul travel from/to the UK	1	5,896	5,896	9,489
Total	13		125,040	201,232
Per capita (for 13 respondents definitely avoiding travel)			9,618	15,479
Per capita (for 89 respondents definitely avoiding travel)			1,405	2,261
Short Haul Travel - Air				
Trip between East Kilbride and London (Air)	8	690	5,520	8,884
Trip between the UK and Europe	1	412	412	663
Plane travel within a DFID region (outside Europe)	3	834	2,502	4,027
Total	12		8,434	13,573
Per capita (for 12 respondents definitely avoiding travel)			703	1,131
Per capita (for 82 respondents definitely avoiding travel)			103	166
Short Haul Travel - Rail				
Trip between East Kilbride and London (Rail)	2	690	1,380	2,221
Other trip within the UK	2	388	776	1,249
Trip between the UK and Europe	1	412	412	663
Total	5		2,568	4,133
Per capita (for 5 respondents definitely avoiding travel)			513	826
Per capita (for 34 respondents definitely avoiding travel)			75	121

Table 182: Number of video conference calls at DFID in 2005

Type of conference	Number of calls
Internal to UK	1708
UK to DFID Overseas	1108
Between DFID Overseas	781
DFID to External	487
Total	4084

Table 183: Estimated savings from video conferencing at DFID

	Number of calls	Avoided distance (miles per capita)	Total avoided distance (miles)	Carbon emissions avoided per mile (kg of CO ₂) ⁵⁸⁶	Total carbon emissions avoided, gross (kg of CO ₂)
Internal to UK	1708				
Rail	341	75	25,575	0.06	1,534
Air, short haul	1367	103	140,801	0.24	33,792
UK to DFID Overseas	1108				
Air, long haul	997	1405	1,400,785	0.17	238,133
Air, short haul	111	103	11,433	0.24	2,744
Between DFID Overseas	781				
Air, short haul	781	103	80,443	0.24	19,306
DFID to External	487				
Rail	122	75	9,150	0.06	549
Air, short haul	122	103	12,566	0.24	3,016
Air, long haul	243	1405	341,415	0.17	58,041
Total			2,022,168		357,115

⁵⁸⁶ Based on Defra, *Guidelines for Company Reporting on Greenhouse Gas Emissions*, Annex 1, July 2005. These conversion factors have been updated since and are available at : <http://www.defra.gov.uk/environment/business/envrp/pdf/conversion-factors.pdf>

Annexe 4: Complementary data for the BT e-work case study

Table 184: Type of work style among surveyed staff

	%	Number
Mainly work at a single BT location, seldom or never work from home	56	594
Work from a variety of locations, but seldom or never work from home	14	145
Mainly work at a single BT location, frequently work from home	9	92
Work from a variety of locations, frequently work from home (and do regard this as my office base)	9	93
Work from a variety of locations, frequently work from home (but don't regard this as my office base)	8	83
Other	4	47
Total	100	1054

Table 185: Avoided commuting distance to a BT office location per e-worker of the Workabout category

Mode	Avoided distance per day (round trip) (miles)	Avoided distance per day (round trip) (km)	Equivalent of CO ₂ emissions in kg per week
Average, all modes	45.81	73.72	-
All cars	29.83	48.01	13.56
<i>Diesel</i>	<i>15.36</i>	<i>24.72</i>	<i>6.76</i>
<i>Petrol</i>	<i>14.47</i>	<i>23.29</i>	<i>6.84</i>
Train	15.36	24.72	1.60
Other	0.63	1.01	-

Table 186: CO₂ emissions related to car trips for personal purposes

Weekly distance arising from use of car capacity by 25 % of Workabout group	1,260 miles (2,027.8 km)
Weekly CO ₂ emissions arising from use of car capacity by 25 % of Workabout group, at 0.28 kg per mile (average car UK Defra 2005)	352.8 kg
Weekly CO ₂ emissions arising from use of car capacity per Workabout person	4.41 kg

Table 187: CO₂ emissions related to additional trips otherwise carried out as part as commuting

Weekly distance arising from special journeys by 50 % of the Workabout group	1,014.4 miles (1,632.52 km)
Weekly CO ₂ emissions arising from use of car capacity by 50 % of Workabout group, at 0.28 kg per mile (average car UK Defra 2005)	284.03 kg
Weekly CO ₂ emissions arising from use of car capacity per Workabout person	3.55 kg

Table 188: Net travel related CO₂ emissions from Workabout scheme

	Tons of CO ₂ for 11,000 Workabout e-worker per year	kg of CO ₂ per Workabout e-worker per week
Avoided by non-commuting	7691.2	15.20
Arising from additional use of car capacity (worst case)	2,231.5	4.41
Arising from additional journeys	1,796.5	3.55
Arising from additional in-work travel	0	0.00
Net reduction on worst case assumption	3663.2	7.24

Table 189: Technologies used when working outside a BT location

	Mobile	Field	E-work	Alternate	Agile	Workabout
Broadband (DSL) access at home	60%	24%	79%	84%	66%	88%
Wi-Fi outside the home and/or BT locations	16%	6%	21%	15%	16%	31%
Blackberry	10%	3%	13%	8%	16%	17%
Internet telephony (Voice over Internet Protocol)	6%	6%	5%	4%	6%	5%
3G (broadband by mobile phone)	1%	1%	0%	0%	0%	0%
None of the above	31%	60%	15%	11%	28%	8%
Responses	165	110	55	15	29	11

Box 2: Economic and social impacts of teleworking

Economic impacts of teleworking

Previous 2002 survey reported that 78% of the respondents considered that they were more productive as a result of shifting to some form of home-based working whilst 3.9% considered they were less productive. Around a fifth (17%) felt there had been no change. Among the factors increasing the productivity, the most significant reported were: reduced disruption, reduced commuting time and stress, flexibility in time and location, and working longer hours.

Only 2% of respondents stated that teleworking had reduced their working hours. In contrast, 68.5% stated that they had increased 29.5% that they had remained the same.

Economic benefits through reduced office space and minimised absenteeism were also reported.

Social impacts of teleworking

The previous 2002 online questionnaire also included social issues. A majority of the teleworkers surveyed also reported an increase in their quality of life despite longer working hours. While the majority (81%) of recent Workabout registrants felt their expectations of the benefits of teleworking had been met, 19% of respondents were finding the drawbacks more significant than expected. The main reason given was difficulty in adjusting to the lack of social interaction in the workplace. Telework was sometimes found to be a factor of social inclusion, with 10% of the respondents reporting that telework had enabled them to stay in employment when they might otherwise have had to leave.

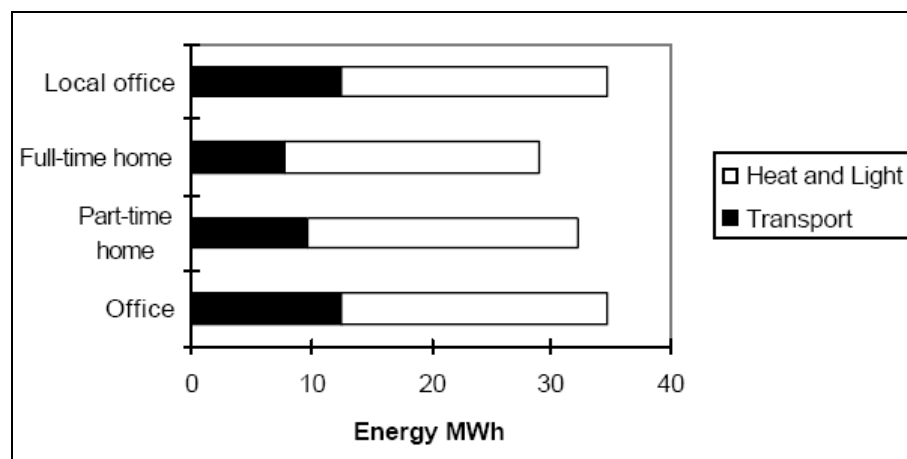
Box 3: Energy use per e-worker

Energy use per typology of worker - Gray, M & Hodson, H. Teleworking Explained, 1993 John Wiley & Sons

In a British study, the difference in energy use per typology of e-worker was depicted (Figure 92). It reveals that depending of the typology of the e-worker, and of the time spent in each location (i.e. home, office, local office) the energy used related to heating and lighting vary with (local) office buildings being the more demanding. Depending of the number of days spent teleworking, and depending of the number of hours spent in each location, the environmental impact of teleworking could be very different. A part time teleworker which still require the use of office space from time to time will not help reduce the office space unless his company sets up a

flexible workplace where employees can share and rent an office space only when needed.

Figure 92: Personal annual energy profiles for four different modes of work⁵⁸⁷



Box 4: Flexible offices

Flexible offices and electricity consumption issues

The number of flexible offices is rapidly growing but is still quite small. The Swedish telecom company Ericsson, has started a project called 'Teambuilding', in which a flexible workplace has been constructed, with 15% less desks than the number of employees. The teleworking scheme at Ericsson is based upon the assumption that at least one fourth of the workforce teleworks out of the office. Some other major Swedish companies that have adopted this idea include Siemens Nixdorf, Tetra Pak, Canon (Canon Rissne, 26 workplaces for 40 employees), and Vattenfall (Globen, 85 workplaces for 140 employees)⁵⁸⁸.

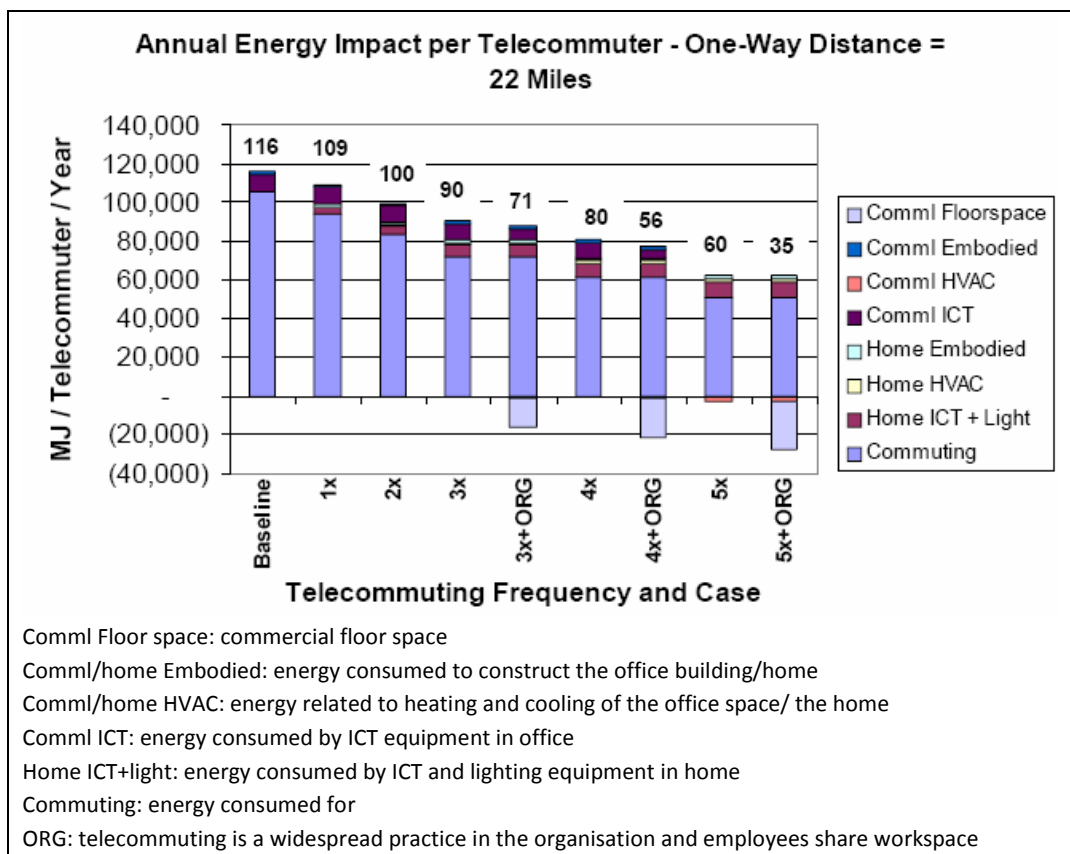
However, it should be noted that this reduction in office space may, on the other hand, lead to a need for larger, well-equipped facilities at the employee's home, or locally based offices (local centres), reducing the net gain. **For instance, the AT&T company estimated that each of its average e-worker spends on average one third or his time at work saved 20 sq. feet of office space, equivalent to 87.5 kWh electricity savings a week (3,500 kWh per year), and added an extra 12.5 kWh/week (500 kWh per year) to his home electricity consumption by an increase**

⁵⁸⁷ Gray, M & Hodson, H. *Teleworking Explained*, 1993 John Wiley & Sons

⁵⁸⁸ Arnfalk, P. *Information technology in pollution prevention: Teleconferencing and telework used as tools in the reduction of work related travel*. International Institute for Industrial Environmental Economics. 1999
[http://www.iiee.lu.se/Publication.nsf/\\$webAll/95A88D4B94B46AC9C1256C3600386C82](http://www.iiee.lu.se/Publication.nsf/$webAll/95A88D4B94B46AC9C1256C3600386C82)

in its occupation time. Therefore the net savings were estimated to 75 kWh per week per e-worker for an average number of days spent at home of 1.67⁵⁸⁹.

Figure 93: Energy savings of telecommuting⁵⁹⁰



⁵⁸⁹ Joseph Romm. *The Internet Economy and Global Warming: A Scenario of the Impact of E-Commerce on Energy and the Environment*. Center for Energy and Climate Solutions. 1999
<http://www.cool-companies.org/energy/ecom.doc>

⁵⁹⁰ TIAXX LLC. *The Energy and Greenhouse Gas Emission Impacts of Telecommuting and E-Commerce*. 2007. For US Consumer Electronics Association (CEA)
http://www.ce.org/Energy_and_Greenhouse_Gas_Emissions_Impact_CEA_July_2007.pdf

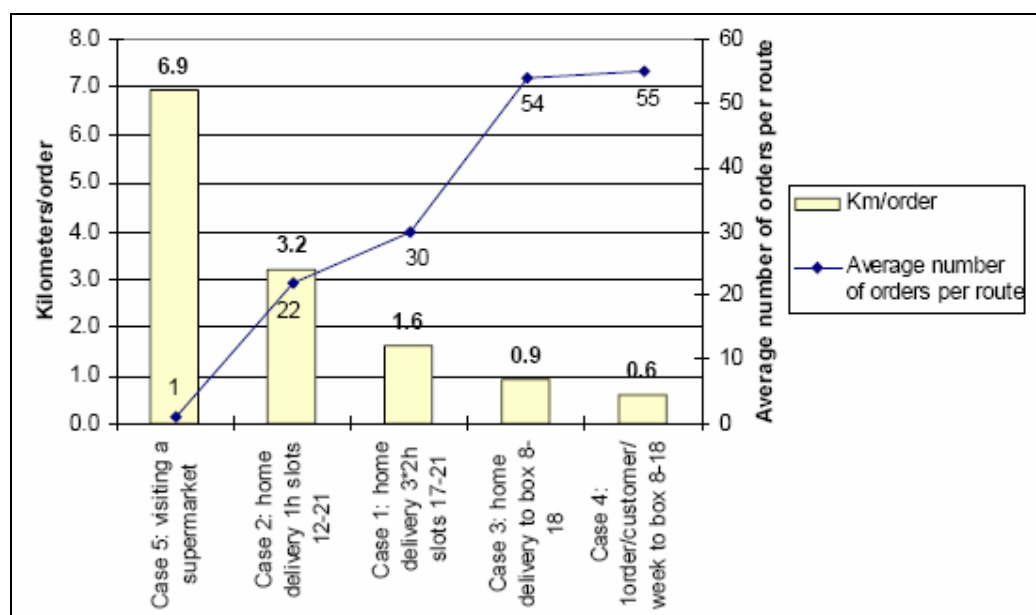
Annexe 5: Complementary data for the Digital Music case study

Table 190: Simplified life cycle assessment of producing one CD

	Inventory		EcoInvent inventory name	Emissions (gCO ₂ eq)	Primary Energy (MJ)
Electricity	1.6E-01	kWh	Electricity, medium voltage, production UCTE, at grid/UCTE U	77.1	1.9
Gas	5.3E-03	m ³	Natural gas, burned in boiler condensing modulating >100kW/RER U	0.0	0.0
Polycarbonates	1.7E-02	tonne	Polycarbonate, at plant/RER S	92.8	1.9
Aluminium	1.0E-05	tonne	Aluminium, production mix, at plant/RER S	0.1	0.0
Foil (PE)	1.0E-03	tonne	Polyethylene, LDPE, granulate, at plant/RER U	2.1	0.1
PS	6.7E-02	tonne	Polystyrene, general purpose, GPPS, at plant/RER S	185.6	6.1
Paper	2.3E-02	tonne	Paper, woodfree, coated, at regional storage/RER S	29.3	1.3
Cardboard	4.7E-03	tonne	Corrugated board, mixed fibre, single wall, at plant/RER S	4.6	0.1
Tap water	3.3E-01	m ³	Tap water, at user/RER S	0.1	0.0
TOTAL				391.6	11.4

Annexe 6: Complementary data for the Finnish online grocery shopping case study

Figure 94: Average distance driven per order and average number of orders per route



Annexe 7 : complementary data for the case study on online book purchase in Japan

Table 191: Categories of goods purchased by online shoppers⁵⁹¹

Product categories	Bought by % of on-line shoppers
Books	66%
CDs, recorded music	58%
Computers and related products	38%
Air travel reservations	26%
Videos, filmed entertainment	19%
Flowers	18%
Event tickets (sport, entertainment)	17%
Food, drink	13%
Men's clothing	12%
Women's clothing	12%

⁵⁹¹ Ernst & Young, (2000), Global Online Retailing, January.

Table 192: Impact of e-commerce compared to traditional retail

Result: E-commerce has: +: a positive effect -: negative effect ±: an uncertain effect compared to traditional retail	Argument	Comment	Source
+ E-commerce consumes less energy than traditional retail	Building energy consumption for traditional retail is 16 times greater than the building energy consumption needed for e-commerce in general	Does not take into consideration the increased residential energy consumption related to an online purchase (Book retail)	Romm et al. (1999) ⁵⁹²
- E-commerce consumes more energy than traditional retail (Energy required for sale and distribution via e-commerce is estimated to 73 MJ/book and 53 MJ/book for conventional retail)	The energy savings from reduced personal transport from e-commerce is offset by increased use of air freight by courier services in US	(Book retail)	Matthews et al. (2001) ⁵⁹³
± In US and in Japan, in case of a dense urban area: e-commerce consumes more energy than traditional retail (9.3 MJ vs. 1.6MJ / book). In Japan, in a rural zone e-commerce consumes less energy (12MJ vs. 16MJ/book).	Extra packaging offsets the savings in terms of personal travel to the bookstore. Multi purpose travel of customers (the customers does not only shop for a book) is often the case and saving only happens in the case of single-purpose shopping trips.	(Book retail)	Williams and Tagami (2001) ⁵⁹⁴
- E-commerce consumes more energy than traditional retail	E-commerce allows savings when considering the distribution phase compared to traditional retail. However, online goods are typically cheaper than in retail outlets. The income saved results in additional consumption leading to extra environmental impacts offsetting the potential savings in e-commerce distribution.	Focuses on the environmental impacts of the income saved from purchasing online (personal computer sale)	Reijnders and Hoogeevee n (2001) ⁵⁹⁵
+ E-commerce consumes less energy than traditional retail	E-commerce consumes less than traditional shopping by car or by bus (respectively 1.7 MJ, 3.6 MJ and 1.9 MJ / book)	Book retail	Reichling and Otto (2002) ⁵⁹⁶

⁵⁹² Romm, J., A. Rosenfeld, and S. Herrman. *The Internet economy and global warming*. 1999. The Center for Energy and Climate Solutions.

⁵⁹³ Matthews, H. S., C. Hendrickson, and D. L. Soh. *Environmental and economic effects of e-commerce: A case study of book publishing and retail logistics*. *Transportation Research Record*. 2001. 1763: 6–12.

⁵⁹⁴ Williams, E. and T. Tagami. *Energy analysis of e-commerce and conventional retail distribution of books in Japan*. 2001. In *Sustainability in the Information Society*, edited by L. Hilty and P. Gilgen. Marburg, Germany: Metropolis Verlag.

⁵⁹⁵ Reijnders, L. and M. J. Hoogeevee. *Energy effects associated with e-commerce: A case study concerning online sales of personal computers in the Netherlands*. 2001. *Journal of Environmental Management* 62(3): 271–282.

⁵⁹⁶ Reichling, M. and T. Otto. *The environmental impact of the new economy: Deutsche Telekom, telecommunications services and the sustainable future*. 2002. In *Ecology of the new economy*, edited by J. Park and N. Roome. Sheffield, UK: Greenleaf Publishing.

Box 5: Details on the calculation of the energy use for making an online book purchase

Energy use for making an online book purchase

The Japanese case study calculates the energy consumption of an online book purchase by estimating the average power consumed by a computer (multiplied by the typical time for making an online purchase), and also by estimating the residential energy consumption related to lighting and heating the home.

As most of the energy consumption during the whole life cycle of a computer is due to the production phase, the production phase of the computer was taken into account in the study, assuming a manufacturing energy of 5,600 MJ per computer.

This number was then divided by the total use phase (assuming a home usage pattern of 2 hours / day, 365 days/year and a lifetime of 3.44 years, i.e. 2,510 hours in total) leading to a “production phase power” of 620 W. The use phase power was then estimated to 70 W, assuming a mix of 50% desktops and 50% laptops.

The power for lighting one room was estimated to 200 W and the energy consumption for heating the room was estimated to 300 W per year, leading to a total power requirement of 1200 W for online purchasing at home.

An estimated time of 15 min was allocated for the purchase of 1 book through e-commerce, with an extra 5 min per additional book purchased.

Multiplying the above power by time used for purchase assuming 1.7 books per purchase, the authors estimate that the average home energy use for on-line purchasing is 0.95 MJ per book.